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A Quantitative Analysis of White-Tailed Deer Harvest Across States and Counties

By

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Bachelor of Science
Clemson University, 2011

Submitted in Partial Fulfillment of the Requirements

For the Degree of Master of Earth and Environmental Resources Management in

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College of Arts & Sciences

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DEDICATION

I want to dedicate this research in memory of my grandfather, John Sengstacken, who was always supportive when it came to my education, as well as my Aunt Jayne, the most amazing woman I had the honor of calling family.

ACKNOWLEDGEMENTS

I would like to gratefully acknowledge the numerous individuals who have helped me these past two years here at the University of South Carolina. First and foremost, I would like to express my very great appreciation to my advisor, Dr. Jill Anderson, for her guidance, patience, and especially her intellectual and motivational support. Her suggestions and criticisms have been instrumental in the completion of my research. I would also like to thank the rest of my committee members: Dr. John Kupfer, Dr. Rudy Mancke, and Mr. Charles Ruth for their valuable criticisms, ideas, and time resulting in the successful completion of this project. Each member of my committee brought a new perspective to the table, and I am thankful you all shared some of your wisdom with me.

I am extremely grateful for the assistance given to me by Dr. Andrew Ortaglia, who helped me run and understand my statistical analyses using SAS©. The Anderson Lab provided excellent constructive feedback, and in doing so I have been able to produce a noteworthy project. I would like to thank the following people/agencies for their assistance with the collection of my data: Charles Ruth of the South Carolina Department of Natural Resources, Charlie Killmaster of the Georgia Department of Natural Resources, Joy Sweaney of the Tennessee Wildlife Resource Agency, Ann May and Ryan T. Myers of the North Carolina Wildlife Resource Commission, Chris Cook of the Alabama Department of Conservation and Natural Resources.

Lastly, I would like to thank my family and friends for their continued support throughout the duration of this research and my academic career.

ABSTRACT

White-tailed deer (*Odocoileus virginianus*) have gone from locally extirpated to overabundant in many areas in the United States since the early 1900s. Ecosystems with chronically overabundant populations experience many disastrous effects resulting from the selective browsing behavior of deer. White-tailed deer are managed at the state level resulting in different management strategies, harvest data collection, and deer management goals between states. However recreational hunting is the primary tool used by wildlife agencies to control population growth. As such, it is beneficial to understand the influence each regulatory variable has on white-tailed deer harvest.

For this research, I compiled historical harvest data records provided by various state wildlife agencies. Correlation, regression and ANOVA procedures were executed on the data. Results suggest that numerous variables have a significant impact on doe harvest, one being hunter effort. Additionally, North Carolina and South Carolina are similar in many ways, but they are not congruent when it comes to white-tailed deer management. Moreover, analyses were conducted to test if areas with longer and earlier beginning hunting seasons than surrounding states result in greater numbers of nonresident hunters. The research suggests that later starting and shorter gun seasons increase the number of nonresident hunters, which is the opposite of what I was expecting to occur. The nonparsimonious models for total harvest and doe harvest indicate that changes in gun season and muzzleloader season regulations are very influential on harvest results.

This research provides a broad understanding of the predicted harvest response to the manipulation of hunting regulations. The body of research also represents the use of applied sciences and statistics in an attempt to discover new and innovative ways to monitor and manage white-tailed deer in the Southeast. One anticipated benefit from this research is to demonstrate the need for states to collect compatible information from their citizen hunters. Such uniformity in the data could provide deer managers with numerous benefits, including an easier time answering the thousands of questions from citizens about deer, and also facilitate more efficient interstate communication concerning problematic trends in the deer herd.

PREFACE

I have enjoyed white-tailed deer for many years as an avid hunter and outdoor enthusiast, but it was not until recently that I discovered my affection for researching the species. During my college undergraduate years, I was curious about the species so I began researching and educating myself on the biology and management of white-tailed deer. Through journal articles, textbooks, and online resources provided by state and federal wildlife agencies I began to realize how very complicated the management of such an adaptable species can be. I also noticed that almost every publication I came across about white-tailed deer management used small study sites. Knowing that white-tailed deer have very small home ranges, these small study sites make sense, but I firmly believe that someone cannot truly understand and appreciate the way that something works without viewing the whole picture. In an attempt to fill this gap in the literature, I wanted to execute research on a much larger scale than most publications concerning white-tailed deer management. After discussing this possibility with my advisor and several wildlife professionals, I decided the best topic for my thesis would be analyzing long-term white-tailed deer harvest data on a large geographic scale. Hopefully this research will instigate a multi-state collaboration with goals to improve harvest data collection and commence constructing a "big picture" for the white-tailed deer species.

This research has been my life for the better part of two years so I hope everyone who reads this learns something, but more importantly enjoys my research.

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LIST OF ABBREVIATIONS

ASD .... Archery Season Start Date

ASL .... Archery Season Length

CL .... Confidence Limit

GSD .... Gun Season Start Date

GSL .... Gun Season Length

JD .... Julian Date

MSD .... Muzzleloader Season Start Date

MSL .... Muzzleloader Season Length

OR .... Odds Ratio

QDM .... Quality Deer Management

WMA .... Wildlife Management Area

WTD .... White-Tailed Deer

CHAPTER ONE

INTRODUCTION

1.1 STUDY RATIONALE

If white-tailed deer (*Odocoileus virginianus*) are not properly managed, an overabundance of the species can result in extensive damage to the ecosystem in which it lives and even negatively impact the herd itself (Rooney & Waller, 2003; Horsley, Stout, & DeCalesta, 2003; Waller & Alverson, 1997; McShea, 2012). Recreational hunting is the primary way that deer managers in each state attempt to control white-tailed deer populations (Stedman, et al., 2004). The species is regulated at the state level, and deer managers set harvest regulations each year based on information they collect about the state's deer herd and the specific management goals of the area (Hewitt, 2011). Therefore, assessing harvest data is of vital importance to deer managers. There are many ways that deer managers can manipulate harvest, such as the hunting weapon type, the number of hunters present, the length of each season, and when the seasons start (Hewitt, 2011). Each state is able to regulate their deer herd as they see fit, but little information is available on how white-tailed deer harvest data compares across states. It is important for deer managers to understand not only what is happening in their state's deer herd, but also the patterns occurring in the surrounding states to better predict possible out-of-state influences on their herd. Using white-tailed deer harvest data is difficult because the information collected and the techniques used differ from state to state.

1.2 RESEARCH QUESTIONS

This research takes a multistate approach to understanding the data collected by wildlife agencies in the southeastern United States and provides possible management implications to help make recreational hunting a more efficient tool in white-tailed deer population control. In particular, this research will cover the following research questions:

1) Do states that share similar demographics, physical locations, climates, physiographic provinces, land use functions, and/or settlement histories use similar management strategies for their white-tailed deer herd? I expect to find that very similar states will have equivalent management strategies, resulting in comparable harvest outcomes.

2) Which is the better predictor for estimating total and doe harvest, hunter effort or the total number of hunters? I predict the hunter effort will be more correlated with total and doe harvest than the total number of hunters.

3) Do counties that allow earlier hunting and/or a longer seasons compared to the surrounding area have a larger number of nonresident hunters traveling to the county to hunt? I anticipate finding that counties in which the hunting season is longer and/or starts earlier than the surrounding counties will have a greater number of nonresident hunters. I do not believe differences in hunting season start dates and season lengths will influence the number of resident hunters.

4) Of the data collected for this research, which variables have the greatest impact on total white-tailed deer harvest and doe harvest? I hope to find that some regulatory

variables have a much greater influence on the predicted total and doe harvest than others.

Through answering each question, this research attempts to analyze white-tailed deer harvest data in a new and innovative way, and gives suggestions for deer managers to make recreational hunting a more efficient population control tool.

CHAPTER TWO

BACKGROUND

2.1 BRIEF HISTORY OF WHITE-TAILED DEER

White-tailed deer (*Odocoileus virginianus*) populations have fluctuated through time. Historically predators, natural mortality, and harvest by Native Americans controlled deer population growth (D'Angelo, 2009). Before Europeans arrived deer were also limited by the lower productivity of old-growth forested habitat that provided few openings where young deer could acquire nutritious vegetation (D'Angelo, 2009). In the early 1900s, unregulated market hunting and habitat loss via commercial logging almost drove the species to extinction (D'Angelo, 2009). Since then excellent management and suburban sprawl have substantially increased population sizes, and many populations have gone from locally extirpated to locally abundant (Warren, 2011). It is now the most wide spread deer species in the world.

White-tailed deer have a large reproductive potential, and in extremely favorable habitats, even doe yearlings are able to breed (Hewitt, 2011). The species easily adapts to a variety of situations (Brown & Cooper, 2006) and successfully exploits the ever-increasing number of anthropogenically-altered habitats (D'Angelo, 2009; Rawinski, 2008). White-tailed deer have also benefitted from the extirpation of major predators (grey wolves and cougars) throughout much of its range (Rawinski, 2008). Although coyotes are present, there is limited evidence showing lower deer densities throughout the coyote's historic range (McShea, 2012). However, new and current research being conducted in South Carolina is showing evidence that coyotes are significantly impacting fawn recruitment. An increase in the number of suitable habitats in combination with a lack of natural predators is primarily responsible for recent deer overabundance. In more than half of the counties lying east of the Mississippi River white-tailed deer populations exceed 12 deer/km^2 (Long, Pendergast, & Carson, 2007).

2.2 SIGNIFICANCE OF WHITE-TAILED DEER POPULATION MANAGEMENT

The total number of white-tailed deer in a population directly affects tree regeneration and studies have demonstrated that deer browsing could depress local regeneration and growth of favored tree species (Rooney & Waller, 2003; Horsley, Stout, & DeCalesta, 2003). This can lead to significant differences in the assemblages of overstory and understory species in old-growth forests (Long, Pendergast, & Carson, 2007). Suppression or elimination of palatable seedlings via deer browsing is resulting in a constant, steady shift of forested ecosystems to less-palatable seedlings (Horsley, Stout, & DeCalesta, 2003). Deer browsing can even be the most important factor in seedling longevity and seedling mortality, more so than climate factors and environmental gradients (Waller & Alverson, 1997). Previous research has shown that slow-growing conifers are particularly sensitive to deer browsing and as deer populations increase there is a decrease in abundance of more-palatable shrubs and herbaceous plants in the deer's range (Waller & Alverson, 1997). These preferred browse species could be impacted at deer densities of 3-10 deer/km^2 (McShea, 2012). To benefit the more palatable species, management activities would need to maintain deer population levels below biological carrying capacity specific to each habitat because this is the point at which deer consume most of the available vegetation in an area and the deer population is unable to sustain growth and reproduction (D'Angelo, 2009). Maintaining lower deer densities, below biological carrying capacity of the habitat, for several years can allow regeneration of understory vegetation to levels beyond susceptibility to deer browsing affects for both tree seedlings and herbaceous plants (D'Angelo, 2009).

Indirect effects can arise from deer browsing on plants through food web interactions, habitat modification (Rooney & Waller, 2003), or trophic level interactions (McShea, 2012). Food web interactions result from direct competition between deer and other herbivorous species. White-tailed deer selectively browse on certain plant species but not others leading to an alteration in the competitive abilities of plant species in that ecosystem (McShea, 2012), favoring less-palatable species over the deer-preferred species. Habitat modification then arises from sustained high deer browsing pressure on tree seedlings and saplings resulting in a change of the forest species composition (Rooney & Waller, 2003; McShea, 2012). This failure of tree regeneration can result in a halting of forest ecological succession due to the reduction of light levels on the forest floor (McShea, 2012) and a shift of habitat can occur where grasses, ferns, and sedges are favored, which can further inhibit tree seedling success (Rooney & Waller, 2003). Many years of deer browsing can lead to significantly different plant species composition in the understory compared to the forest canopy (Long, Pendergast, & Carson, 2007).

Studies have also shown that the density of deer populations has an influence on the physical condition of the herd itself (Keyser et al. 2005; Leberg & Smith, 1993). Individuals in high deer populations have been reported to have lower body masses, decreased survival, and smaller litter sizes (Leberg & Smith, 1993). The sexual dimorphism of the species leads to different responses to environmental stresses between the sexes. Females tend to focus their energy on accumulating fat reserves, while males focus their energy on acquiring as many females as they can (Keyser, Guynn Jr, & Hill Jr, 2005). Since male deer reach their maximum weights at later ages than females do, they are more likely to be negatively affected by increases in population density than females (Leberg & Smith, 1993). When the density of adults in a given population is high, males devote more energy to competition, which can reduce their growth rates and increase male death rates during winter from starvation and susceptibility to diseases (Leberg & Smith, 1993).

2.3 RECREATIONAL HUNTING AS MANAGEMENT TECHNIQUE

Based on the ecological evidence, white-tailed deer populations today are overabundant on the east coast of the United States and need to be managed to ensure intact, diverse forested ecosystems. However, the current numbers of natural predators and significant habitat modification are ineffective at controlling deer populations (McShea, 2012) and other methods must be considered. D'Angelo (2009) describes several methods to manage deer populations: sport hunting, professional deer removal, relocation, and fertility controls. In many areas of the United States, live trapping and relocation of deer is not an option due to high cost, disease transmission risk, and lack of suitable release sites. After relocation, most relocated deer do not survive a year in their new environments (Conover 2002, as sited by DeNicola & Williams 2008). Fertility controls are expensive, do not directly reduce abundance, but are a highly effective mechanism for reducing the reproductive output of females. However when fertility controls combine with increased deer mortality, the potential exists for limiting populations near human developments (McShea, 2012).

Recreational hunting is usually the most economically feasible option and is the primary management tool used by agencies to control deer populations (Stedman, et al., 2004) because it is cheap and alone has the capacity to reduce population densities of white-tailed deer drastically (Leberg & Smith, 1993). Management agencies can manipulate harvest size, duration of the hunting season, harvest limits, equipment allowed, sex restrictions, and the number of licenses or permits given out each year to try and control deer harvest. However, without the cooperation and active participation of citizen hunters, this method would to be ineffective at controlling deer populations.

2.4 CHALLENGES FACING DEER MANAGERS

"The North American Model" refers to the reliance on citizen hunters to achieve management goals (McShea, 2012). Because of this reliance, it is critical to determine how hunters will respond to certain management decisions. If managers want to use recreational hunting as a population management technique for white-tailed deer, an increase in hunter effectiveness (or "success"), the number of deer harvested as a function of days hunted, is necessary and can be accomplished through a better understanding of hunter behavior in the field. Stedman et al. (2004) showed that hunter density was negatively correlated with distance from roads and also that hunters preferred the use of stand hunting in the mornings with more stalking and walking during the evenings. Using studies like Stedman et al. (2004), a better understanding of the human dimensions involved in hunting can help to define appropriate education programs for hunters (Warren, 2011).

Hunters tend to hunt in areas where they will have the highest probability of obtaining a quality deer, or trophy bucks, even when they know the management intent is to reduce deer population density (McShea, 2012). Hunters also tend to be more satisfied with their hunts when they harvest a trophy buck so selective harvesting for these bucks is a common practice seen in recreational hunting. Unfortunately, females are the determinant for population size because population growth is dependent on the number of females present in a deer population. Therefore selectively harvesting for trophy bucks might give hunters "bragging rights", but does not effectively help control the population. With respect to increased male competition within high density deer populations, population demographics should be the focus when deciding on selective harvesting restrictions, rather than attempting to change the genetic makeup of the population to potentially produce trophy bucks (Webb, Demarais, Strickland, DeYoung, Kinghorn, & Glee, 2012). "Quality Deer Management" is an aspect of the North American Model whose guidelines encourage decreasing deer densities to produce higher quality deer (McShea, 2012).

As with natural predators, hunter harvest can be influenced by environmental factors, and a better understanding of these factors can provide guidelines for more efficient population management. Hunters differ from natural predators in that hunters only impact population numbers, but the presence of natural predators can also alter deer browsing behavior (McShea, 2012). In the presence of natural predators white-tailed deer are more skittish and do not forage as often, reducing browse pressure on tree seedlings and herbaceous plants (McShea, 2012). Thus, it is difficult for hunters alone to maintain preferred browse species unless deer are reduced significantly below biological carrying capacity, which can still be achieved through understanding hunter behavior and managing hunter actions (McShea, 2012). Recreational hunters are only in the field for a limited period of time throughout the year and are usually restricted to daylight hours. Therefore, the hunters can potentially influence the behavior of deer by altering the timing the deer browse time to a more nocturnal schedule, but this does not alter the amount of browse consumed. It is the constant, year-round threat of attack by natural predators that cause white-tailed deer to become more vigilant, reducing the browse pressure on preferred plant species.

Different hunt types produce different harvest size outcomes. Information on harvest size and hunter effectiveness is useful because both of these aspects of hunting can influence deer population size and growth (Weckerly, Kennedy, & Stephenson, 2005). Weckerly et al (2005) used days hunted as a rough measure of hunter effort and showed a positive relationship between hunter effort and harvest size. The lowest harvest rates of all the hunt types in the study were buck-only gun hunts, buck-only muzzleloader hunts, and either sex archery hunts. Conversely, the doe-only gun hunts showed the highest harvest sizes and are considered the most effective at changing the rate of population growth by reducing female population size (Weckerly, Kennedy, & Stephenson, 2005).

CHAPTER THREE

METHODS

3.1 CREATING THE DATABASE

Over the course of two years through working on this research, I have created the very large database used to complete the objectives previously stated.

3.1.1 DATA COLLECTION

To compile the dataset used for the analysis, I contacted the wildlife agencies responsible for managing each state's white-tailed deer population to request historical records on harvest, estimated population size, the number of hunters, and other information relating to deer management. Through email correspondence, phone calls, and meetings, I collected white-tailed deer harvest data from various wildlife agencies in the southeastern United States. I collected both county- and statewide data, depending on the level of data collection of the state. Some information was located through browsing on the agency's webpage (e.g. hunting laws).

3.1.2 MISSING STATES/DATA

There are gaps in the data and some states were excluded from this research for various reasons. Some states (e.g. Florida) collected their harvest data in a vastly different format than other states, making direct comparisons difficult. Another reason was if the agency wanted to have influence over this research in exchange for the requested data. Other states simply did not collect the data I was hoping to gain access to. For example, Georgia does not collect any data at the county level.

3.2 CALCULATING HUNTING SEASON START DATE AND LENGTH

Once I was able to find the date each hunting season began, I converted the calendar date to its corresponding Julian Date for each county. To find the season length, I used a calendar and counted the total number of days for each season. For this research, the hunting season length is defined as the total number of days hunters are allowed to use the specified weapon type.

3.3 USING SAS

To fully answer the proposed research questions, I ran correlations, regressions and ANOVAs (SAS version 9,4) on my dataset to make my conclusions based on statistical findings from the data I was able to collect.

3.3.1 COMPARING SIMILAR STATES

To compare the distribution of the different dependent variables being compared, I chose to produce boxplots with the state as the category. The generalized linear model procedure (PROC GLM) was used in constructing these boxplots. Plotting the information allowed for comparisons of many different attributes between the states, such as: mean, median, interquartile range (variability), maximum, and minimum. With this information I compared and contrasted North Carolina with South Carolina. Other, more dissimilar, states were used to contrast the two Carolinas. To determine if significant differences in means existed, an Analysis of Variance (ANOVA) was performed on the data to obtain the Duncan's Multiple Range Test for each boxplot. This information allowed for stronger interpretations of the means for the many dependent variables.

3.3.2 HUNTER EFFORT & HUNTER NUMBER CORRELATIONS

Since counties and states vary in size, it was necessary to use the density (square miles) of each variable to calculate the appropriate measures. Using the Spearman correlation procedure I analyzed the correlation between total effort and the number of hunters with total, doe, and buck harvest densities (PROC CORR). The Spearman correlation option was important, because it uses a nonparametric measure of the statistical dependence of my variables. Since my data was in a raw count form, I could not assume random errors in my data followed a normal distribution or had a constant variance. Thus the nonparametric option needed to be performed since Spearman correlation procedure does not make any assumptions about the shape of the data. The Spearman correlation coefficient (r) and the p-values were then used to make some conclusions about the data at both the state and county levels. I then used the SAS ODS Graphics designer (SAS version 9.4) to make a visual representation of my correlation data using scatter plots. The dependent variables total harvest density (total number of deer per square mile) and doe/buck harvest density (the number of doe/buck deer harvested per square mile) were plotted against the independent variables hunter number density (hunters per square mile) and hunter effort density (number of days hunted per square mile). Since hunter effort was a better predictor of both total harvest and doe harvest, it is important to understand how changes in management could influence hunter effort in your management area. To comprehend how manipulations to the hunting season lengths and start dates could influence the total effort of citizen hunters, I estimated and interpreted the odds ratio and 95% confidence intervals for each of the hunting season variables (see section 3.3.5 for more detail about the odds ratio).

3.3.3 RESIDENT VS. NONRESIDENT HUNTERS

To determine how the number of resident and nonresident hunters is impacted by changes in the hunting season parameters (season length and start date), I ran a regression with a negative binomial distribution (PROC GENMOD, SAS version 9.4). I modeled the dependent variables, number of nonresident and number of resident hunters, for season start dates, season lengths and the county's proximity to the state border. I could not use the Poisson distribution, because I could not assume an equal mean and variance with my count data. Because the negative binomial distribution does not make this assumption like the Poisson distribution, I specified for the negative binomial distribution for the regressions. To determine how manipulations to the hunting season lengths and start dates could influence the number of nonresident hunters in the county, I estimated and interpreted the odds ratio and 95% confidence intervals for each of the hunting season variables (see section 3.3.5 for more detail about calculating the odds ratio).

3.3.4 MODELING TOTAL HARVEST AND DOE HARVEST

The first method I use to model the total harvest and doe harvest was a parsimonious method. I found the best model for predicting total and doe harvest by using a method similar to the backward elimination method for choosing the best model in multiple linear regressions. I began with the full model containing the many regulatory variables deer managers can manipulate. Each time I ran the regression I eliminated the least significant variable until all remaining regressor were significant, p-value < 0.05.

Both models used a negative binomial regression (PROC GENMOD, SAS version 9.4), and began with all the variables in my database that deer managers could manipulate to alter annual harvest. Gun Season Length, Archery Season Length, Muzzleloader Season Length, Gun Season Start Date, Archery Season Start Date, Muzzleloader Season Start Date, Individual Hunter Effort, Habitat Area (square miles), Either Sex Archery Season Length (days), and Either Sex Gun Season Length (days) are the variables used in the model. I also used a negative binomial regression and modeled total and doe harvest using only hunting season start dates for the regressors and another model using only the hunting season lengths for the regressors. Although these models are not parsimonious, they allowed me to see the influence of each independent variable (season length and season start date) on total harvest and doe harvest.

3.3.5 OBTAINING THE ODDS RATIO

Obtaining the odds ratio was important because it allowed me to more clearly interpret and explain my results. Using PROC GENMOD (SAS version 9.2) with negative binomial distribution and log for the link, I wrote an estimate statement to calculate the odds ratio for each variable. An example of one of the estimate statements used is: estimate 'Beta GunSeasonLength' GunSeasonLength 1 -1/exp. I then subtracted the odds ratio estimate from 1 and multiplied by 100 to obtain the percent change in the dependent variable for a 1 percent increase in the independent variable.

3.4 USING ArcGIS SOFTWARE

Maps were created to provide visual representations of my data that could not be clearly shown using another media. Also, calculating the predicted amount of habitat and the proximity to the state border was important information to find and include in my various regression models.

3.4.1 CALCULATING HABITAT AREA

To account for variations in the amount of suitable habitat predicted for white-tailed deer within and across states, I used data from the Southeast GAP Analysis Project Species Modeling Report on White-tailed Deer (Southeast GAP Analysis Project, 2011). Using the zonal statistics spatial analysis tool in conjunction with the tabulate area tool and basic math, I estimated of the amount of habitat (mi^2) for each county (Figure 3.1).

3.4.2 CALCULATING COUNTY DISTANCE FROM BORDER

I calculated the geographic distances from the closest bordering state for each county to test the effect of distance on my predicted variable. I wanted to understand how the hunting season lengths and starting dates influenced the variable being predicted in my numerous models when the county's proximity to the state border was taken into account (i.e. the distance variable s held fixed).

3.4.3 MAP VISUALS

I obtained the county shapefiles from the ArcGIS online resources and joined the shape file to a table with the attributes I wanted to map. I used the gradual colors option to map the percent doe of total harvest, percent habitat of the county, length of each hunting season, and the percentage of nonresidents. For all of the maps, I used the natural breaks (Jenks) method to determine where the class breaks were to occur. Using this method, classes are determined by the data. To map what month each of the seasons started, I used the categories option and selected the season (gun, archery, or muzzleloader) for my value field. The map overlay was accomplished by including a layer with the graduated symbols on top of the other layers to show the number of resident and nonresident hunters in a county.

3.5 CHAPTER FIGURES

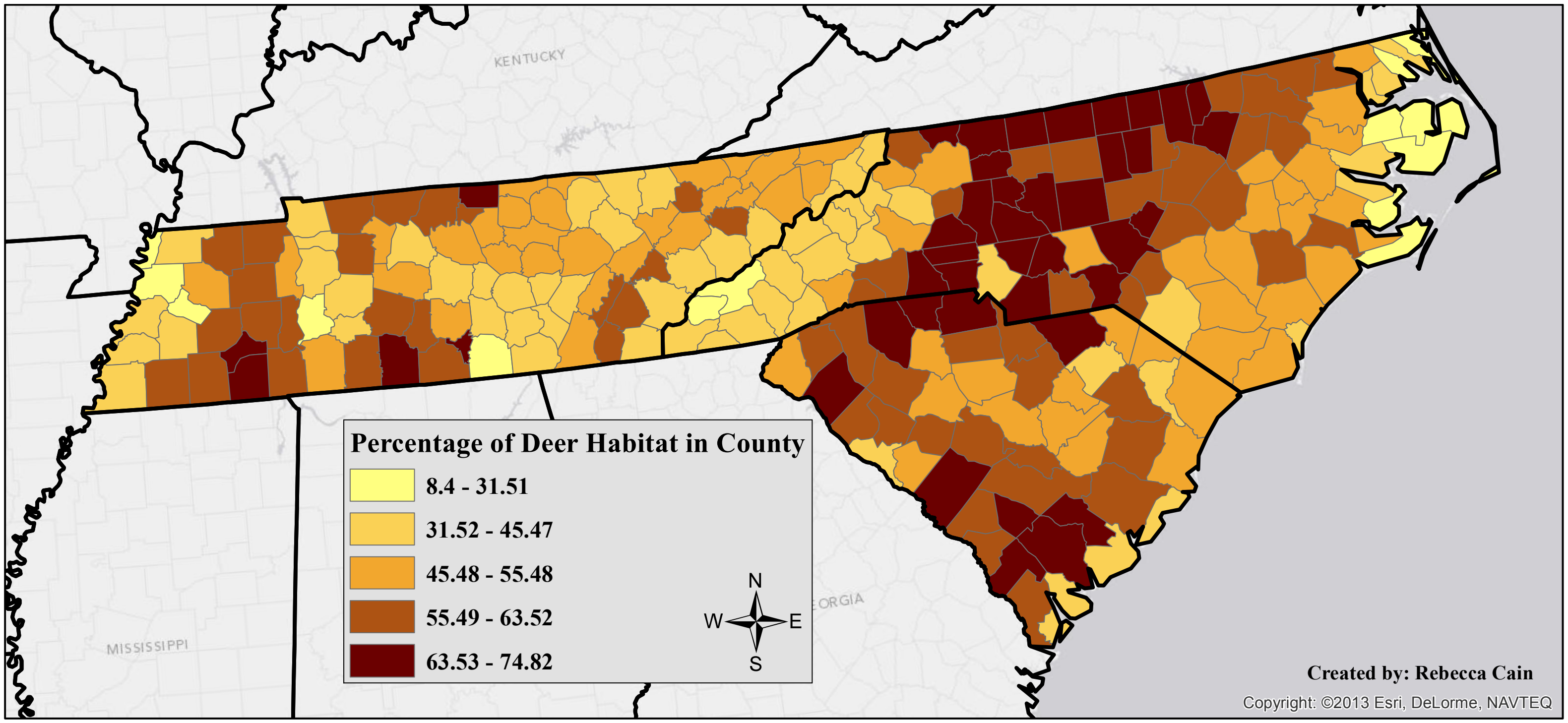

Figure 3.1: Percentage of County that is Predicted Deer Habitat Based on the Southeast GAP Analysis Project Data

CHAPTER FOUR

COMPARISON OF SIMILAR STATES

4.1 JUSTIFICATION FOR FOCAL STATE SELECTION

North Carolina and South Carolina are adjacent and have similar climates. Similarly, they have the same physiographic provinces: Upper and Lower Coastal Plain, Sandhills, Piedmont, and Blue Ridge (Ecoregions of North and South Carolina Map, 2002). Finally, agriculture is a large part of both states, and they grow the same crops (soybeans, corn, cotton, wheat, etc.) (South Carolina Department of Agriculture, 2014; State Climate Office of North Carolina, 2014).

Both North Carolina and South Carolina have recently experienced rapid human population growth, resulting in rapid growth and expansion of residential, industrial, and commercial areas. Ultimately this rapid human expansion leads to deer habitat loss/fragmentation (Hewitt, 2011). Although the breeding chronology of white-tailed deer does vary a great deal across the Southeast, the Carolinas' deer herds breed around the same time without a lot of variability (Hewitt, 2011). Therefore another similarity is that neither state needs to concern themselves with complications that arise when setting hunting seasons for areas with asynchronous breeding chronology. With so many similarities between the states, I hypothesized that their management practices would be similar, leading to similar harvest outcomes and estimated population.

4.1.1 SETTING UP CONTRASTING STATES

To determine how similar North Carolina and South Carolina white-tailed deer management strategies and harvest outcomes, I used other states with similar data available as contrasting states. Tennessee was used for most of the county-level data analyses were preformed. Alabama, Georgia, and Tennessee were used when state-level analyses were preformed and the data analyzed was collected by the state.

4.2 TOTAL HARVEST COMPARISON

The mean total white-tailed deer harvest is significantly greater for South Carolina than North Carolina at the county level (Figure 4.1, Table 4.1). North Carolina's total harvest is more comparable to Tennessee than to South Carolina at the county level, because North Carolina and Tennessee have nearly equivalent means and their variability is also similar at the county level (Figure 4.1, Table 4.1).

South Carolina's mean total harvest is still significantly larger than North Carolina's total harvest when analyzed at the state level (Figure 4.1, Table 4.1). Alabama and Georgia have the two largest total harvests. The mean total harvest for North Carolina is not significantly different than the mean total harvest for Tennessee.

South Carolina's mean total harvest density is significantly greater than all the other states (Table 4.2). North Carolina's total harvest density data showed less variability than South Carolina (Figure 4.1). Additionally, the mean total harvest density for Tennessee and North Carolina were not significantly different.

4.3 BUCK HARVEST COMPARISON

The mean buck harvest is significantly greater for South Carolina than North Carolina and Tennessee when data collected at the county level was analyzed (Table 4.1).

North Carolina's buck harvest is more equivalent to Tennessee than to South Carolina at the county level (Figure 4.2), because North Carolina and Tennessee have nearly equal means that are not significantly different (Table 4.1). The variability shown by North Carolina and Tennessee is also similar at the county level analysis (Figure 4.2), and the variability is greater for South Carolina than for North Carolina and Tennessee.

When buck harvest is analyzed at the state level, Alabama and Georgia have the largest buck harvests (Figure 4.2). At the state level, the mean buck harvest for South Carolina was not significantly different than the North Carolina or Tennessee buck harvest means (Table 4.1). The variability of South Carolina's data is greater than the variability in North Carolina and Tennessee's data.

When the differences in the sizes of each state were taken into account, South Carolina's mean buck harvest density was once again significantly larger than North Carolina's (Table 4.2). North Carolina and Tennessee were no longer significantly different from each other. The variability was still much larger for South Carolina than for North Carolina (Figure 4.2)

4.4 DOE HARVEST COMPARISON

The mean doe harvest is significantly greater for South Carolina than North Carolina at the county level (Table 4.1). North Carolina's mean doe harvest is more equivalent to Tennessee than to South Carolina (Table 4.1). The variability shown by North Carolina and Tennessee is also similar at the county level, and the variability is larger for South Carolina than for North Carolina and Tennessee (Figure 4.3).

When doe harvest is analyzed at the state level, the mean doe harvests of North Carolina and Tennessee are similar, but North Carolina shows more variability (Figure

4.3, Table 4.1). Alabama and Georgia have the most variability, as well as significantly larger doe harvests than North and South Carolina (Figure 4.3). Unlike at the county level analysis, the mean doe harvest for North Carolina, South Carolina, and Tennessee are not significantly different from one another when the state data was analyzed.

When the differences in the size of the states are taken into account, the mean doe harvest density for South Carolina becomes significantly larger than the mean doe harvest density for North Carolina and Tennessee (Table 4.2). North Carolina has the smallest doe harvest density of all the states (Figure 4.3), but North Carolina's doe harvest density is not significantly different from Tennessee's doe harvest density.

4.5 PERCENT DOE COMPARISON

South Carolina's percent doe harvest mean was significantly higher than North Carolina and Tennessee at the county level analysis (Table 4.3). The South Carolina data shows less variability at the county level (Figure 4.4). North Carolina data is more similar to Tennessee data than to South Carolina data at the county level (Figure 4.4). South Carolina's average percent doe in total harvest is closer to 50%, while North Carolina's average percent doe is around 40% at the county level (Table 4.3). The percent doe harvest varies between the counties of North Carolina, South Carolina, and Tennessee. South Carolina appears to contain a greater proportion of counties with larger percent doe harvest than North Carolina and Tennessee (Figure 4.5).

When analyzed at the state level, there are no significant differences detected between the mean percent doe harvests of North Carolina and South Carolina (Table 4.3). North Carolina's percent doe harvest shows a smaller amount of variability compared to

South Carolina, with an average slightly greater than 40% (Figure 4.4). Alabama, Georgia, and South Carolina appear to have the most amount of variability (Figure 4.4).

4.6 TOTAL NUMBER OF HUNTERS COMPARISON

At the county level, North Carolina and South Carolina show no significant difference in their number of hunters (Table 4.3). Both the North and the South Carolina data are positively skewed, but North Carolina shows slightly more variability than South Carolina (Figure 4.6).

At the state level, the average number of white-tailed deer hunters is significantly greater in North Carolina than in South Carolina (Table 4.3), and North Carolina has greater variability (Figure 4.6). South Carolina's mean is significantly lower than all the states analyzed (Table 4.3). Georgia has the greatest number of hunters and most variability (Figure 4.6). These significant differences in the number of hunters between the states are likely due to the differences in the size of the state.

When differences in the sizes of the states are taken into account, Tennessee has the largest mean hunter density of all the states, however it is not significantly different than South Carolina or Georgia (Table 4.4). South Carolina data showed the smallest amount of variability (Figure 4.6). North and South Carolina's mean hunter densities are not significantly different from one another (Table 4.4).

4.7 TOTAL HUNTER EFFORT COMPARISON

At the county level, the mean total hunter effort is significantly higher for South Carolina than for North Carolina (Table 4.3). Total hunter effort data appears to be more variable for North Carolina than for South Carolina (Figure 4.7).

North Carolina has a significantly larger mean total white-tailed deer hunter effort than South Carolina at the state level (Table 4.3). North Carolina data shows more variability than South Carolina (Figure 4.7). Georgia has the largest mean total white-tailed deer hunter effort (Table 4.3) and shows the most variability of all the states analyzed (Figure 4.7). Significant differences in total hunter effort of the states are likely due to the differences state sizes.

When the differences in the sizes of the states are taken into consideration, mean hunter effort density for South Carolina is greater than North Carolina, but the difference in the means is not significant (Table 4.4). North Carolina once again shows more variability than South Carolina (Figure 4.7). The mean hunter effort for Georgia is significantly greater than all the other states analyzed (Table 4.4).

4.8 SEASON LENGTHS COMPARISONS

The length of the seasons refers to the number of days hunters are able to use the specified weapon type. In South Carolina, all weapon types may be used during the gun season, but only archery equipment can be used during the archery season. In other states, the hunting season specifies the only weapon type allowed during that time. Unlike in South Carolina, in these states during the gun season hunters are only allowed to use gun equipment (i.e. no archery or muzzleloader equipment).

South Carolina has a significantly longer mean gun season length than North Carolina and Tennessee (Table 4.5, Figure 4.8, Figure 4.9). South Carolina's mean gun season length is about 110 days, and North Carolina's mean gun season length is about 60 days (Table 4.5). North Carolina's mean gun season length is significantly longer than the mean for Tennessee. The longer mean gun season lengths of South Carolina can be

South Carolina has a significantly longer mean archery season length, around 125 days, than North Carolina and Tennessee (Table 4.5, Figure 4.8, Figure 4.10). North Carolina has the shortest mean archery season length at slightly less than 40 days (Table 4.5). The mean archery season length is significantly longer for Tennessee than North Carolina. Tennessee's mean archery season length is about 100 days. North Carolina and South Carolina show similar variability in archery season length, and both states have greater variability in their data than Tennessee (Figure 4.8).

South Carolina also has a significantly longer mean muzzleloader season length, about 110 days (Table 4.5, Figure 4.8, Figure 4.11). North Carolina has the shortest muzzleloader season length at around 10 days, and the data shows no variability (Figure 4.8). Tennessee's mean muzzleloader season length of about 50 days is significantly longer than the mean for North Carolina (Table 4.5). Tennessee's mean muzzleloader season length does not display much variability, and South Carolina has the largest amount of variability of mean muzzleloader season length (Figure 4.8).

4.9 SEASON START DATES COMPARISONS

South Carolina has the earliest mean gun season start date at just prior to 260 Julian Days, and the greatest variability in start dates (Table 4.6, Figure 4.12, Figure 4.13). The mean guns season start date for South Carolina is significantly earlier than North Carolina and Tennessee. North Carolina has a mean gun season start date around 310 Julian Days, with the earliest start date slightly before 300 Julian Days (Figure 4.12). The mean gun season start date is significantly earlier in North Carolina than in Tennessee (Table 4.6, Figure 4.12).

South Carolina also has a significantly earlier mean archery season start date, just after 240 Julian Days, than North Carolina and Tennessee (Table 4.6, Figure 4.12, Figure 4.14). South Carolina has the greatest variability in the start date of its archery season (Figure 4.12). North Carolina has the least amount of variability, and its mean archery season start date is just after 250 Julian Days. The mean archery season start date is significantly earlier for North Carolina than for Tennessee (Table 4.6). Tennessee's mean archery start date is just before the 270 Julian Date (Table 4.6, Figure 4.12).

South Carolina has the earliest mean muzzleloader season start date just before the 260 Julian Date, and the greatest variability in start dates (Figure 4.12, Figure 4.15). South Carolina's mean muzzleloader season start date is significantly greater than the mean season start date for North Carolina and Tennessee (Table 4.6). North Carolina has a mean muzzleloader season start date just after 280 Julian Days (Table 4.6). The mean muzzleloader season start date is significantly earlier for North Carolina than for Tennessee (Table 4.6). Tennessee's mean muzzleloader season start date is around the 310 Julian Date (Table 4.6, Figure 4.12).

4.10 SEASON HARVEST COMPARISONS

South Carolina has the highest mean gun harvest density at about 6.5 deer harvested by gun weapons per square mile (Table 4.7, Figure 4.16). The mean gun harvest density is significantly larger for South Carolina than for any other states in the analysis (Table 4.7). The mean gun harvest densities for Georgia, North Carolina, and Tennessee are not significantly different from each other. Additionally, North Carolina and Tennessee show similar variability in their gun harvest density (Figure 4.16).

South Carolina has the highest archery harvest density (Table 4.7). None of the mean archery harvest densities are significantly different for the states in the analysis. South Carolina's mean archery harvest density is around 0.5 deer harvested by archery weapons per square mile, and North Carolina has a mean about 0.21 deer harvested by archery weapons per square mile (Table 4.7). North and South Carolina show similar variability (Figure 4.16). Tennessee's mean archery harvest density is about 0.46 deer harvested by archery weapons per square mile (Table 4.7).

The mean muzzleloader harvest density is significantly higher for Tennessee than for Georgia, North Carolina, and South Carolina at around 0.91 deer harvested by muzzleloader weapons per square mile (Table 4.7, Figure 4.16). South Carolina has the smallest muzzleloader harvest density mean at 0.22 deer harvested by muzzleloader weapons per square mile, with the least variability. Additionally, North Carolina has more variability than South Carolina, and has the second smallest mean of 0.29 deer harvested by muzzleloader weapons per square mile (Figure 4.16). However, the mean muzzleloader harvest density is not significantly different between North Carolina and South Carolina. Georgia's mean muzzleloader harvest density is significantly greater than South Carolina, but is not significantly different than North Carolina (Table 4.7).

4.11 CHAPTER FOUR CONCLUSIONS

North Carolina and South Carolina do not seem to have similar management strategies or outcomes. The mean harvest for all three types was significantly larger for South Carolina than North Carolina at the county level. The mean harvest for the three types differed when the analysis was performed using the statewide data. However when the difference in the sizes of the states was accounted for, the mean harvest density for

South Carolina was significantly larger than the mean for North Carolina. North Carolina's total, buck, and doe harvests were more similar to Tennessee than to South Carolina when the county data was analyzed.

The mean percentage of doe deer was significantly higher in South Carolina than North Carolina at the county level. This could be due to the fact that South Carolina has been emphasizing doe deer harvest longer than North Carolina has been (South Carolina Department of Natural Resources, 2013; North Carolina Wildlife Resources Commission, 2014). The mean total number of hunters was not significantly different between North Carolina and South Carolina at the county- or state level when the differences in state sizes were taken into consideration. However, when total hunter effort was analyzed at the county level South Carolina's mean was significantly higher than North Carolina's mean. This is important because it shows that although North and South Carolina have about the same number of hunters per county, South Carolina hunters are spending a greater number of days hunting. This difference between the hunter effort in North and South Carolina could be a contributing factor to the differences seen in the white-tailed deer total, buck, and doe harvest types of the states. When the same information was analyzed at the state level using hunter effort density, the North Carolina and South Carolina means were not significantly different. However, the mean hunter effort density was still higher for South Carolina than for North Carolina.

When hunting season length is defined as mentioned previously, the South Carolina mean season lengths for all three seasons (gun, archery, and muzzleloader) are significantly longer than the mean season lengths for North Carolina and Tennessee. The shortest archery season length in South Carolina is still much longer than the longest archery season length in North Carolina. The sheer length of South Carolina's hunting seasons could explain why the different harvests are larger in South Carolina than North Carolina.

The mean starting dates of all the hunting seasons are earlier in South Carolina then North Carolina and Tennessee. The entire state of South Carolina has started gun season before the first county in North Carolina does. The gun season start dates vary from county to county for both states, but South Carolina varies more so than North Carolina. The mean start date for archery in North Carolina occurs after the mean start date in South Carolina, but prior to South Carolina's maximum. This means North Carolina's archery season begins after most, but not all, of the counties in South Carolina. North Carolina's muzzleloader season start dates median occurs just prior to South Carolina's maximum. Therefore, similar to what was found with the archery season start dates, North Carolina's muzzleloader season begins after most, but not all, of the counties in South Carolina. The earlier start dates of South Carolina's hunting seasons could also explain why the different harvests are larger in South Carolina than North Carolina. Especially since these earlier start dates are coupled with the longer seasons of South Carolina.

The gun harvest density was significantly higher for South Carolina than North Carolina. This is most likely due to the earlier start and longer season for guns in South Carolina previously discussed. South Carolina also has a higher archery harvest density than North Carolina, but this difference was not significant. This is most likely due to the longer archery season in South Carolina, and that most of the South Carolina counties have started their archery season before North Carolina starts theirs. The median muzzleloader density for North Carolina was slightly larger than the South Carolina median. This is opposite of expected, because North Carolina has a shorter and later starting muzzleloader season than South Carolina. However it should be noted that the median muzzleloader harvest densities for the Carolinas are not significantly different.

In summary, the total, buck, and doe harvests of North Carolina more closely resemble harvest in Tennessee than South Carolina. White-tailed deer population estimates are generally constructed from the harvest data (Rosenberry, Fleegle, & Wallingford, 2011); therefore it is reasonable to assume that similar harvests will lead to similar population estimate. From my results, it would seem that the population estimates for North and South Carolina would be different. My hypothesis that similar states will have similar management strategies was not supported with these findings.

4.12 CHAPTER TABLES

Table 4.1: Total, Buck, and Doe Harvest Means for States at the County and State Level Analyses

	Total Harvest		**Buck Harvest**		**Doe Harvest**	
	County	State	County	State	County	State
Alabama	NA	248858	NA	205500	NA	150429
Georgia	NA	238279	NA	159872	NA	165845
North Carolina	1636.02	104973	933.39	92176	702.63	68517
South Carolina	5080.21	195711	2647.43	112217	2432.76	83494
Tennessee	1711.78	80412	969.76	92128	742.01	70491

NA= Not Applicable

Table 4.2: Total, Buck, and Doe Harvest Density (deer/mi^2) Means for States

	Total Harvest Density	Buck Harvest Density	Doe Harvest Density
Alabama	4.7475	3.9203	2.8697
Georgia	4.0097	2.6903	2.7908
North Carolina	1.9505	1.7127	1.2731
South Carolina	6.1121	3.5046	2.6076
Tennessee	1.9064	2.1842	1.6712

Table 4.3: Percent Doe, Total Number of Hunters, and Total Effort (days hunted) Means for States at the County and State Level Analyses

	Percent Doe		Total Hunters		Total Effort	
	County	State	County	State	County	State
Alabama	NA	40.947	NA	190136	NA	5921956
Georgia	NA	46.709	NA	276366	NA	5921956
North Carolina	39.3994	42.399	3206.8	212902	41809	3243805
South Carolina	46.9584	37.632	3084.6	141888	48161	2218126
Tennessee	39.738	43.164	NA	200972	NA	NA

NA= Not Applicable

Table 4.4: White-tailed Deer Hunter Density (hunters/mi^2) and Hunter Effort Density (days hunted/mi^2) by State

	Hunter Number Density	Hunter Effort Density
Alabama	3.6272	56.526
Georgia	4.6507	99.654
North Carolina	3.9559	60.272
South Carolina	4.4312	69.273
Tennessee	4/7646	NA

NA= Not Applicable

Table 4.5: Gun, Archery, and Muzzleloader Season Length (days) Means for States

	Gun Season Length	Archery Season Length	Muzzleloader Season Length
North Carolina	58.91	37.77	13.81
South Carolina	110.413	124.9348	114.3261
Tennessee	38.716	100.4605	52.4079

Table 4.6: Gun, Archery, and Muzzleloader Season Start Date (Julian Date) Means for States

	Gun Season Start Date	Archery Season Start Date	Muzzleloader Season Start Date
North Carolina	311.09	251.4	284.93
South Carolina	256.9348	242.3478	253.0217
Tennessee	324.5	268.5	309.75

Table 4.7: Gun, Archery, and Muzzleloader Harvest Densities (deer/mi^2) Means for States

	Gun Season	Archery Season	Muzzleloader Season
Georgia	3.2255	0.4671	0.32173
North Carolina	2.4792	0.2133	0.29334
South Carolina	6.5675	0.5073	0.2235
Tennessee	2.487	0.4619	0.9072

4.13 CHAPTER FIGURES

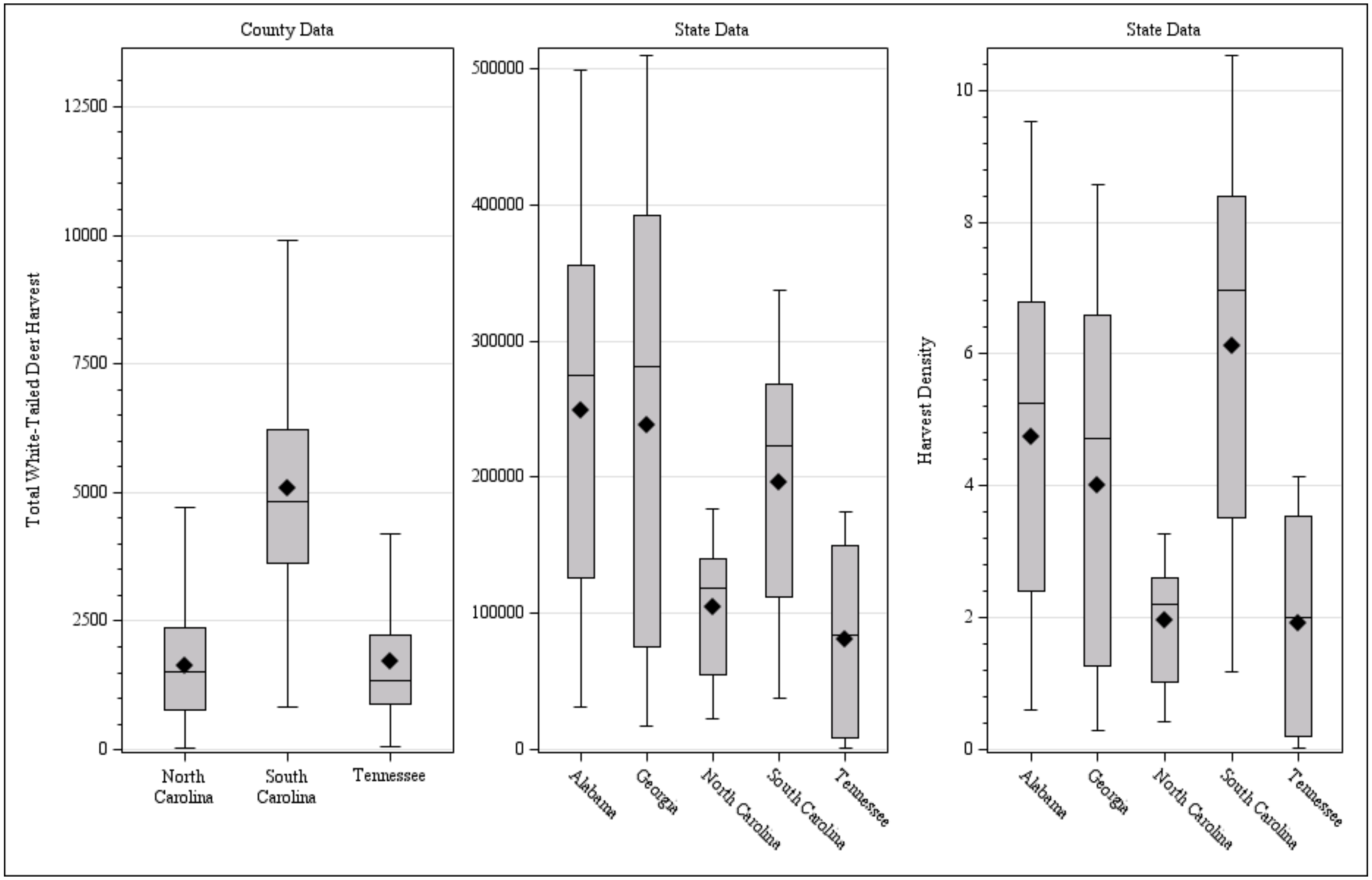

Figure 4.1: Total Harvest (deer) and Total Harvest Density (deer/mi^2) by State

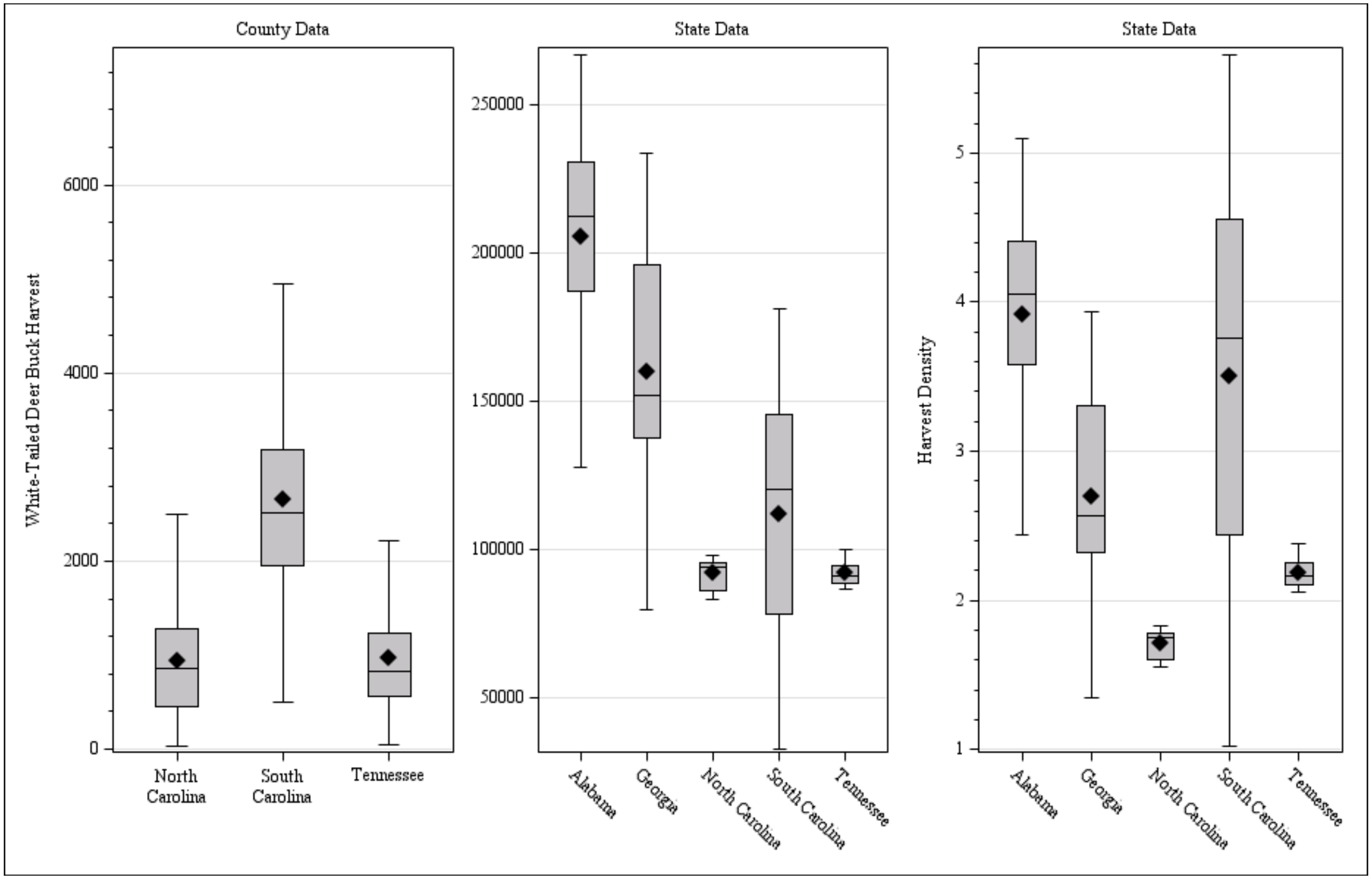

Figure 4.2: Buck Harvest (deer) and Buck Harvest Density (deer/mi^2) by State

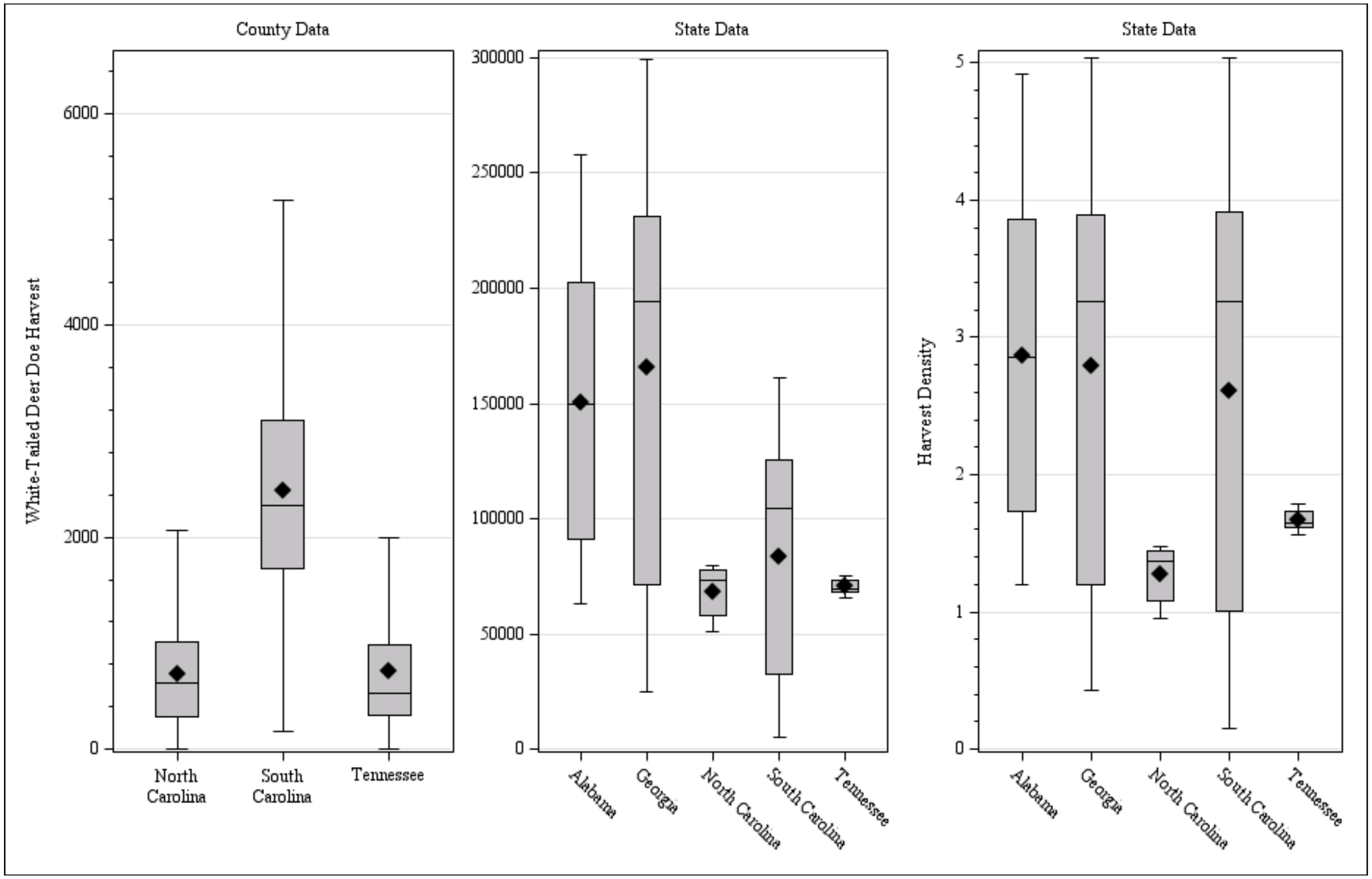

Figure 4.3: Doe Harvest (deer) and Doe Harvest Density (deer/mi^2) by State

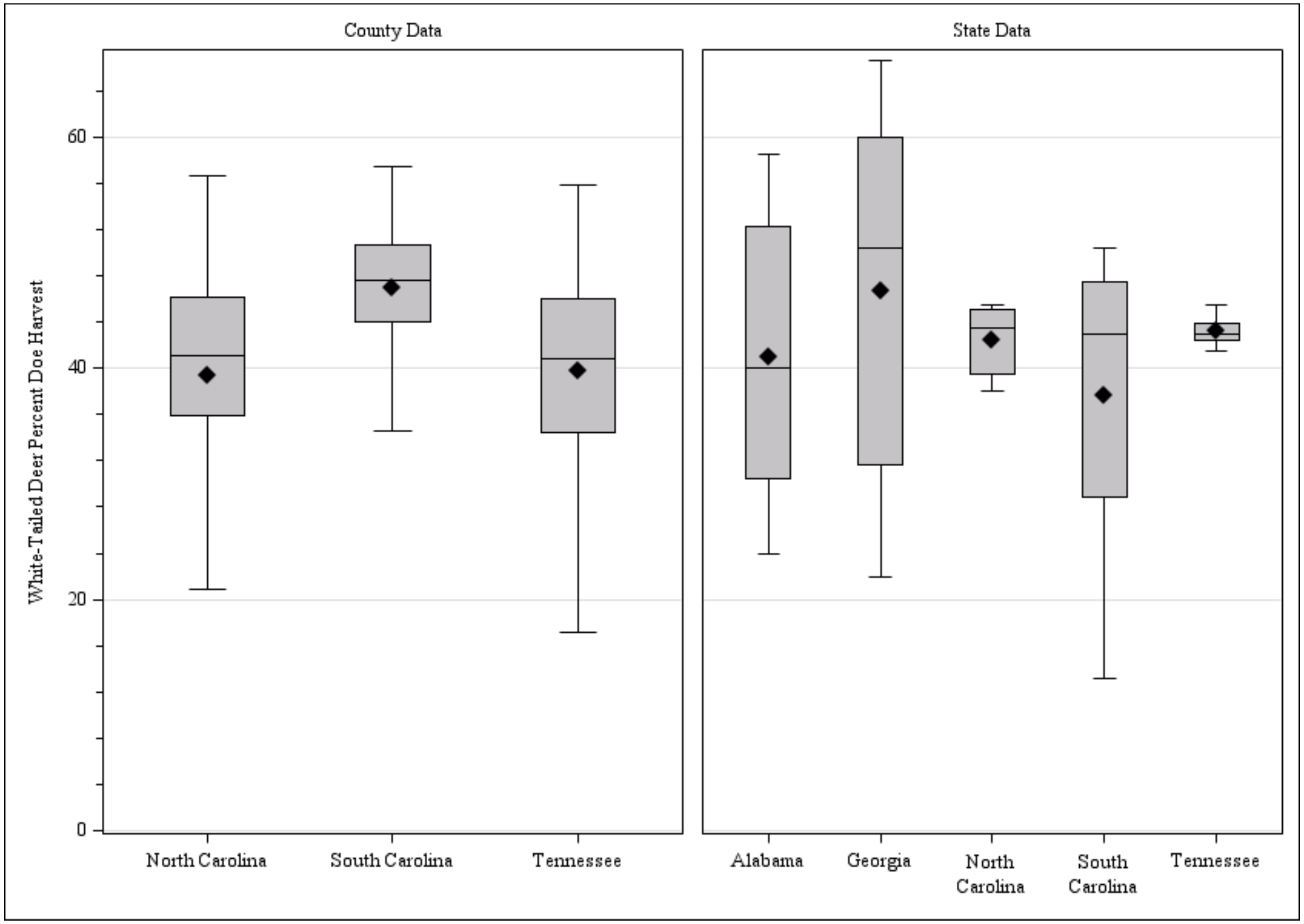

Figure 4.4: Percent Doe Harvest by State

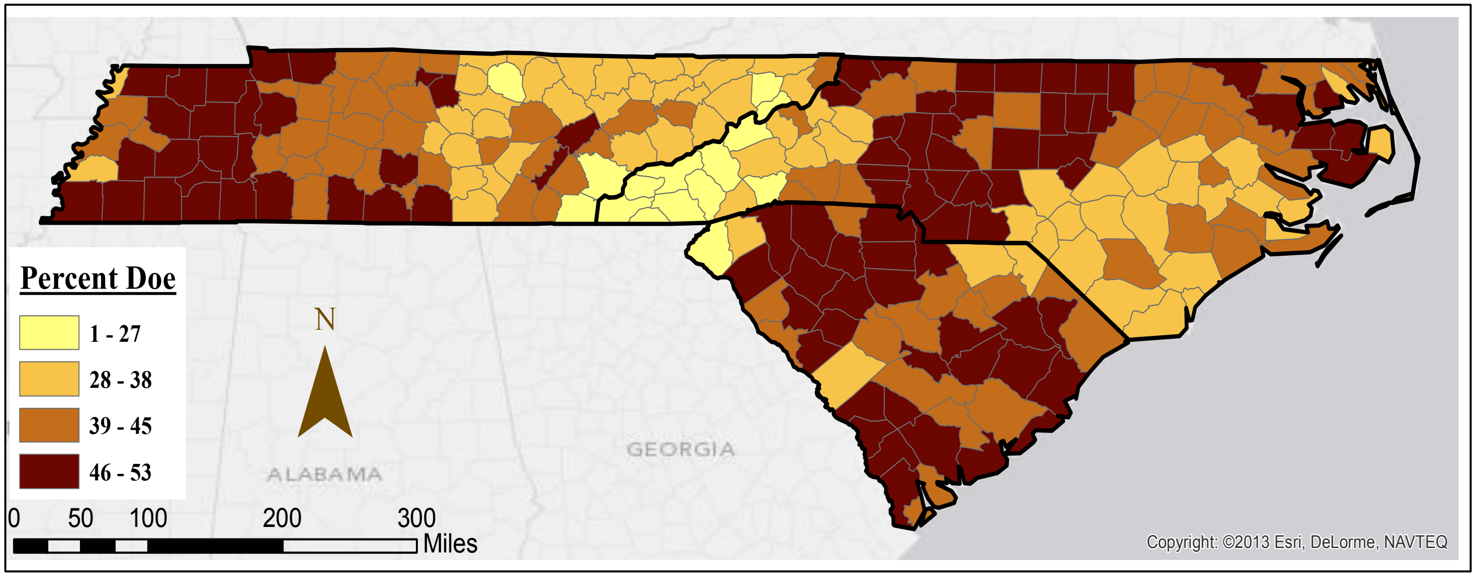

Figure 4.5: Map Displaying Percent Doe for North Carolina, South Carolina, and Tennessee Counties

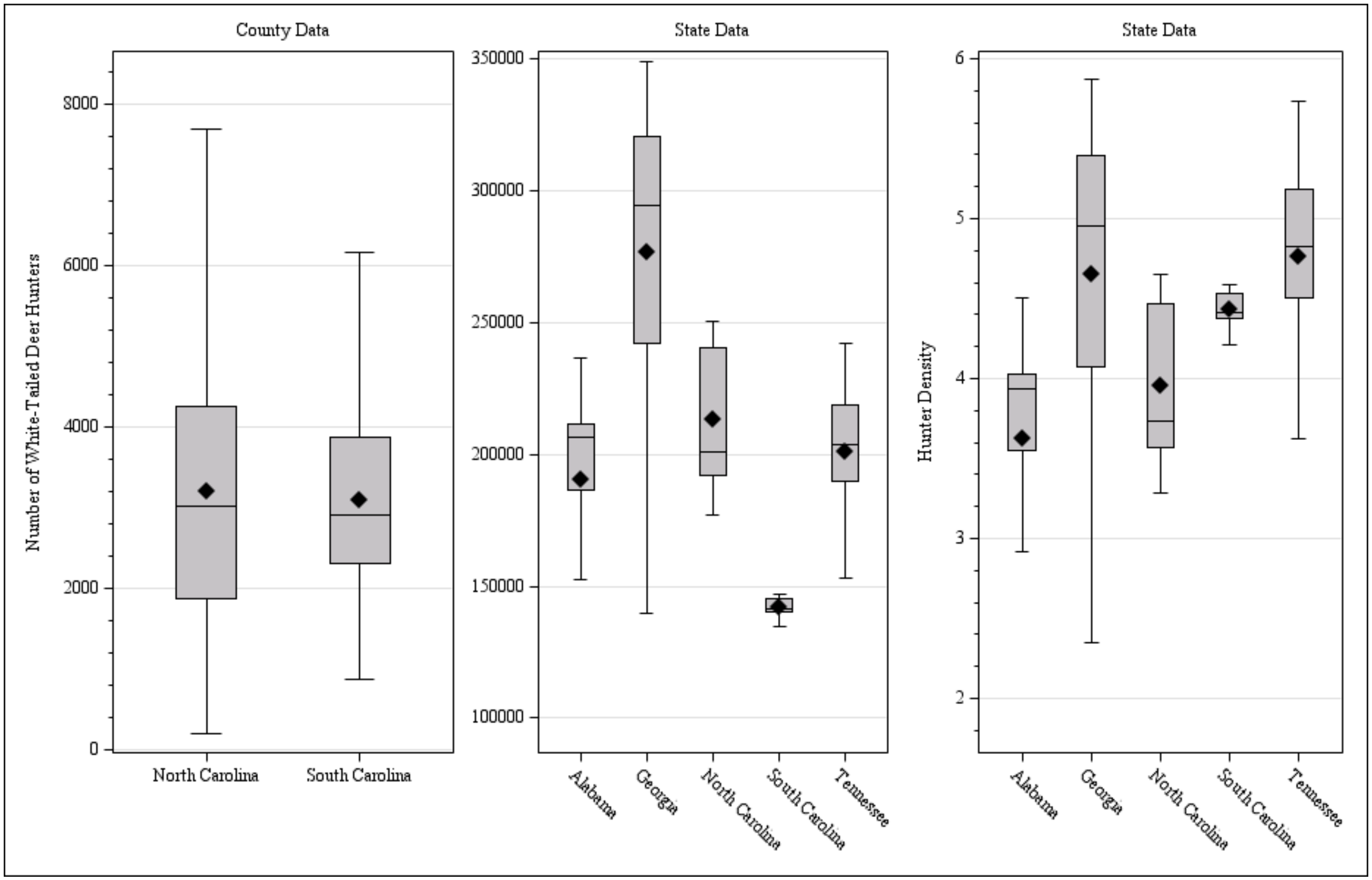

Figure 4.6: Total Number of Hunters and Hunter Density (hunters/mi^2) by State

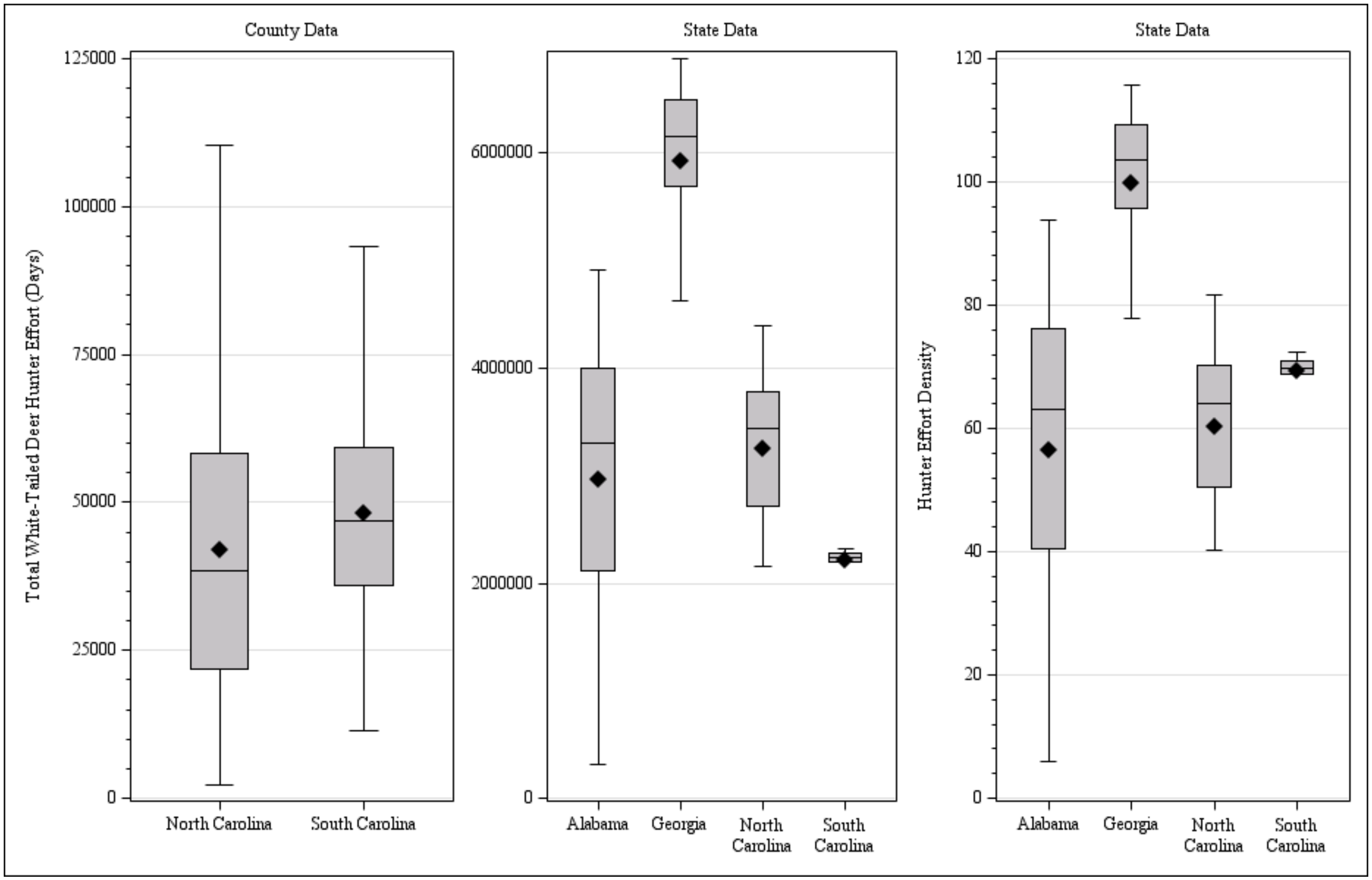

Figure 4.7: Total Hunter Effort (days) and Effort Density (days hunted/mi^2) by State

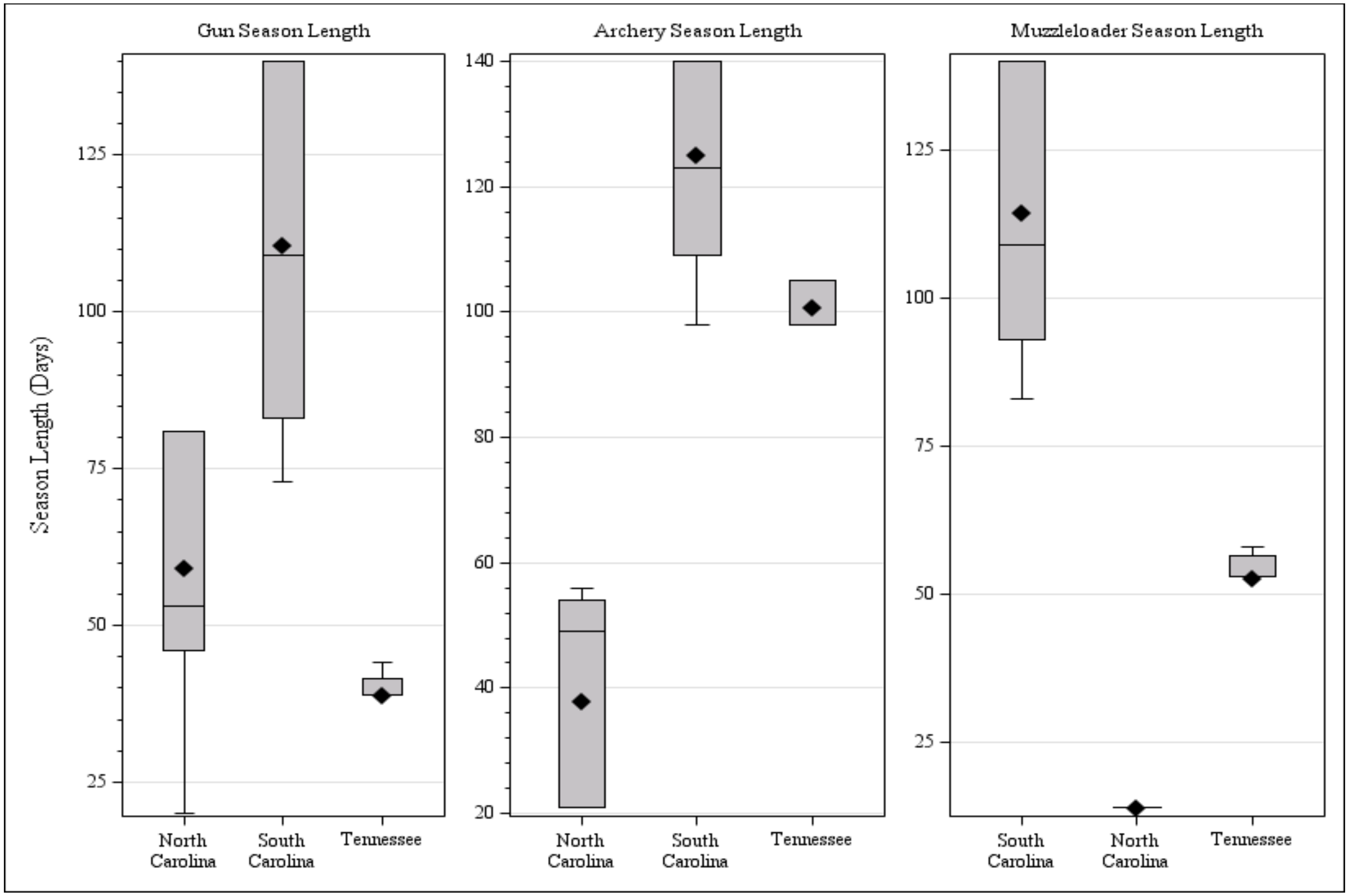

Figure 4.8: Season Lengths (days) of Each Hunting Season Type by State

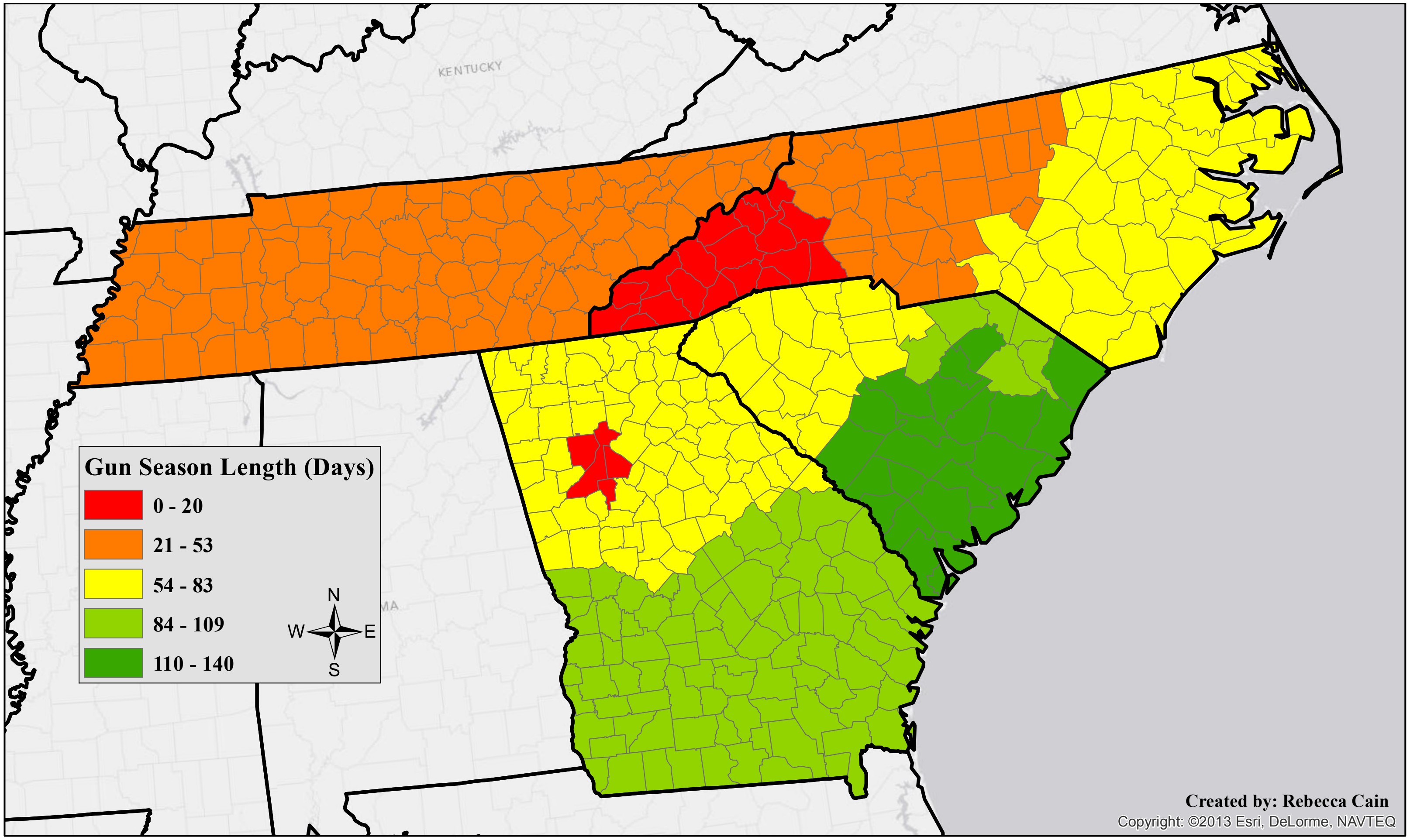

Figure 4.9: Map Displaying the Gun Season Length (days) for each county in Georgia, North Carolina, South Carolina, and Tennessee

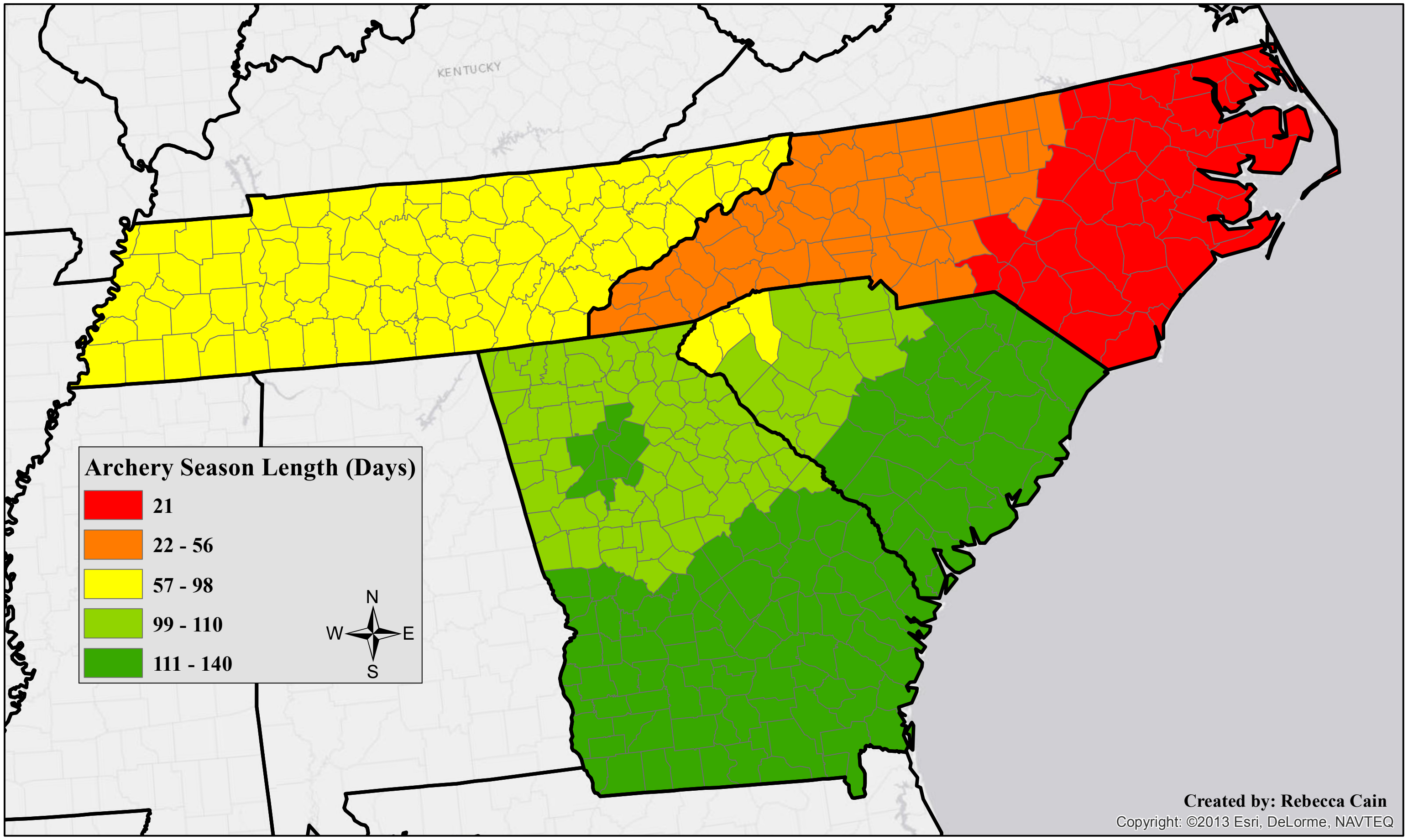

Figure 4.10: Map Displaying the Archery Season Length (days) for each county in Georgia, North Carolina, South Carolina, and Tennessee

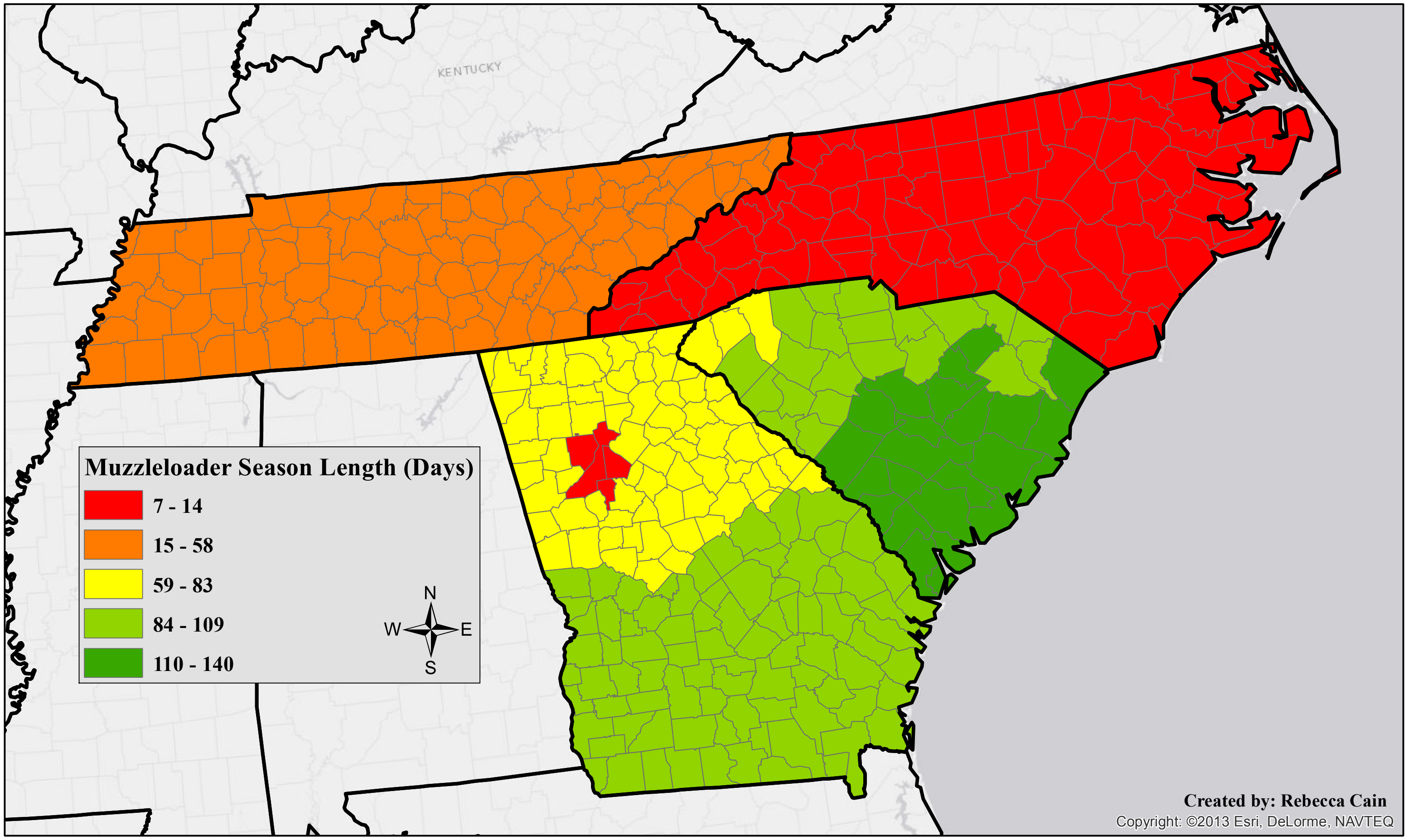

Figure 4.11: Map Displaying the Muzzleloader Season Length (days) for each county in Georgia, North Carolina, South Carolina, and Tennessee

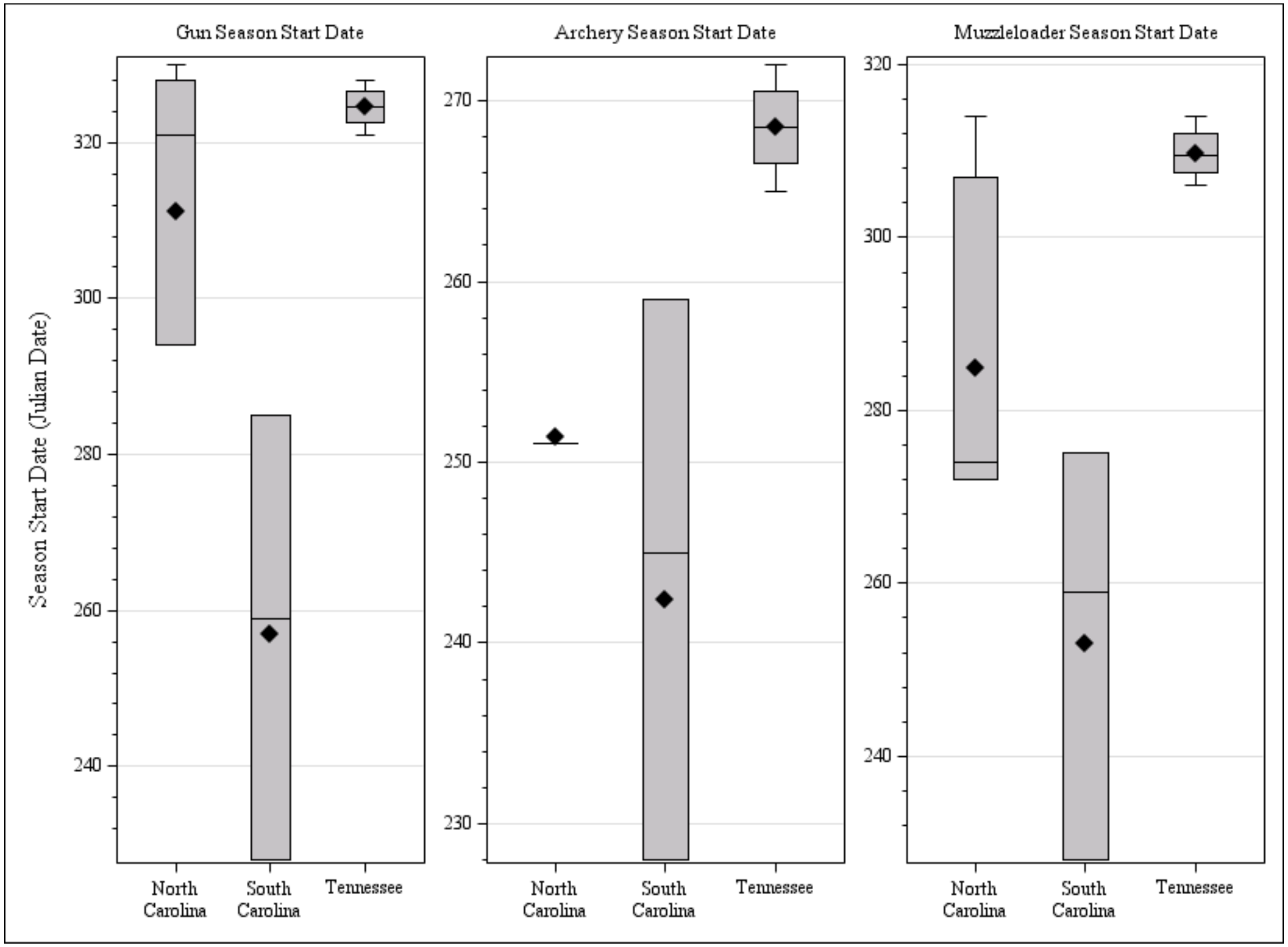

Figure 4.12: Season Start Dates (Julian Date) of Each Hunt Type by State

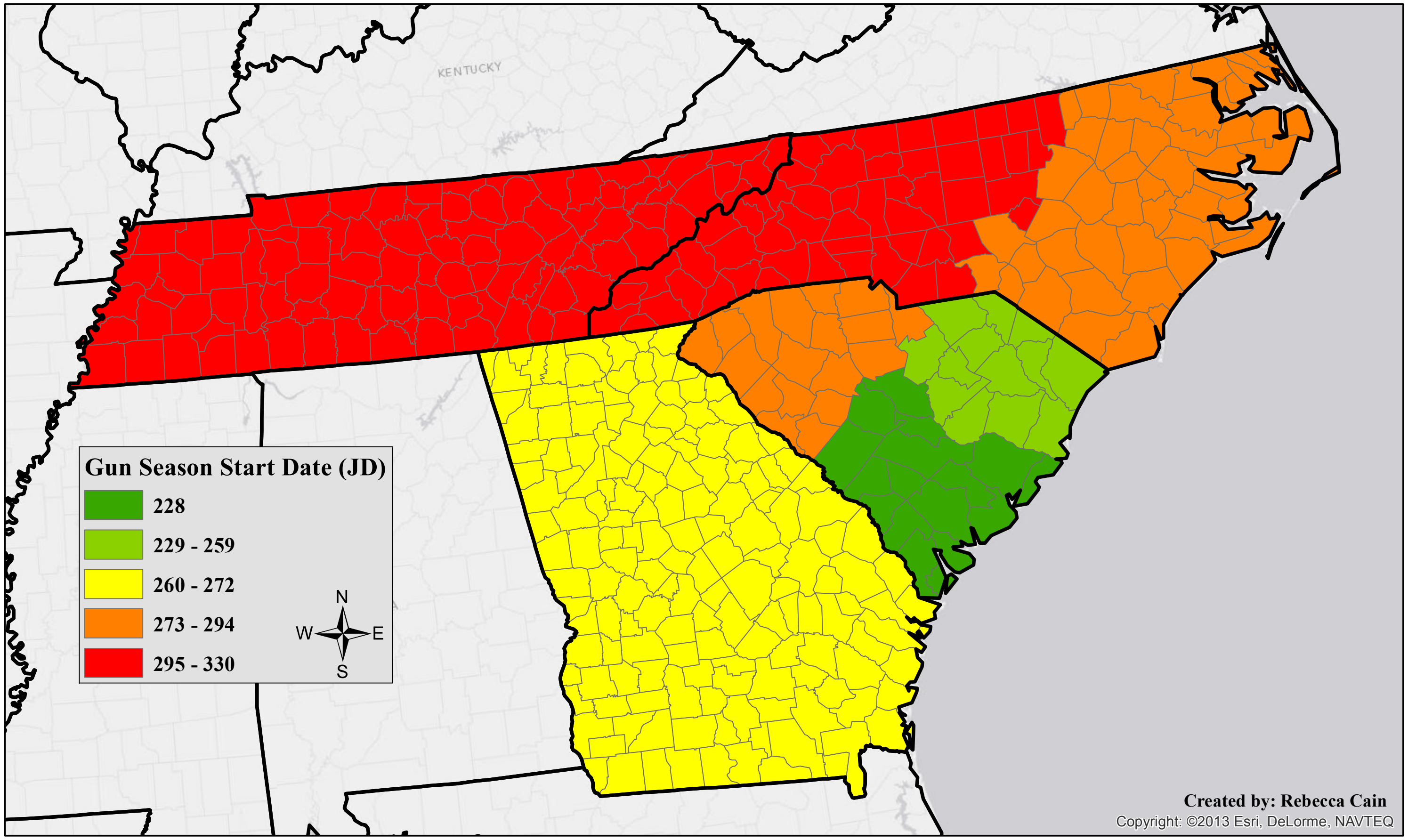

Figure 4.13: Map Displaying Gun Season Start Dates (Julian Date) for each county in Georgia, North Carolina, South Carolina, and Tennessee

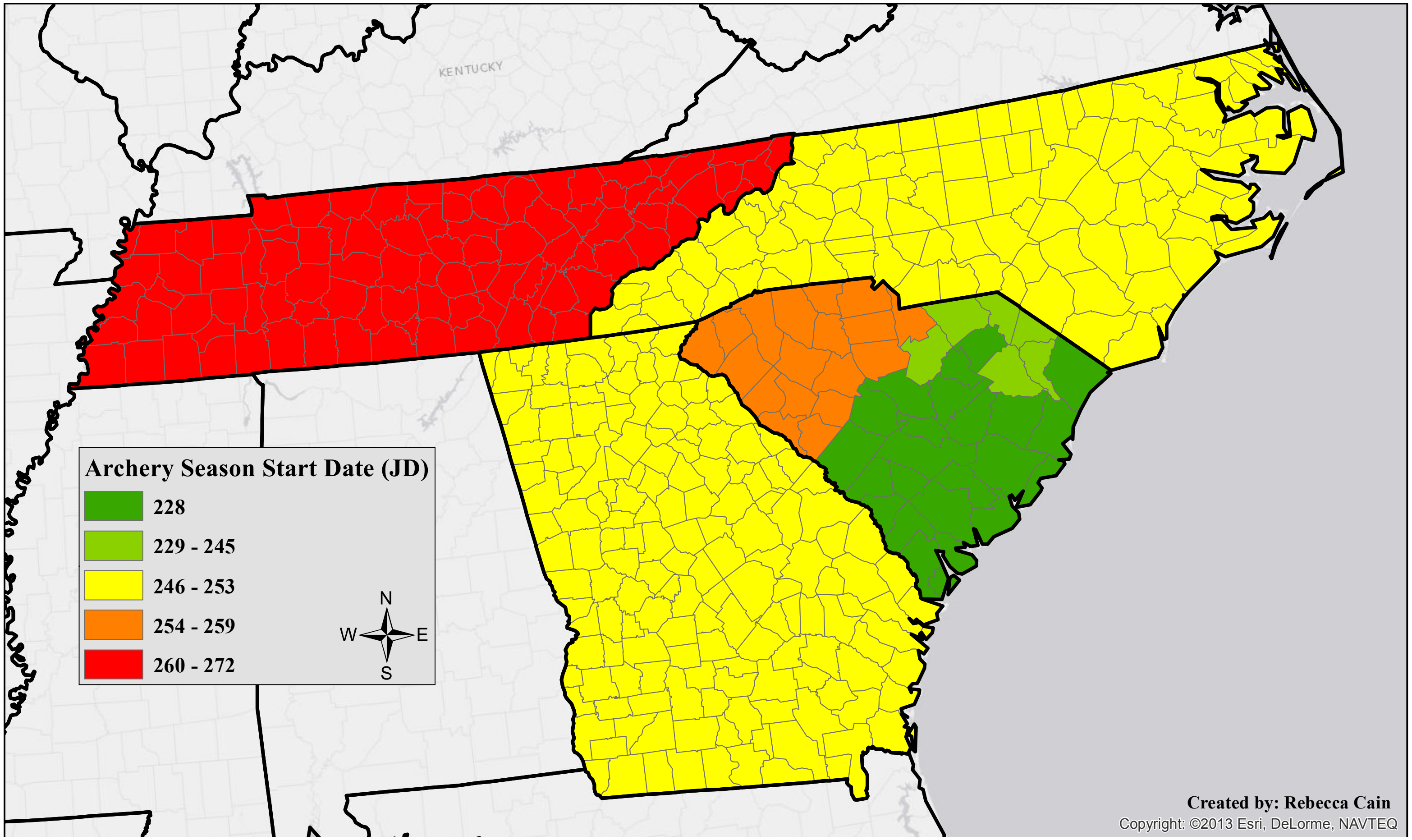

Figure 4.14: Map Displaying Archery Season Start Dates (Julian Date) for each county in Georgia, North Carolina, South Carolina, and Tennessee

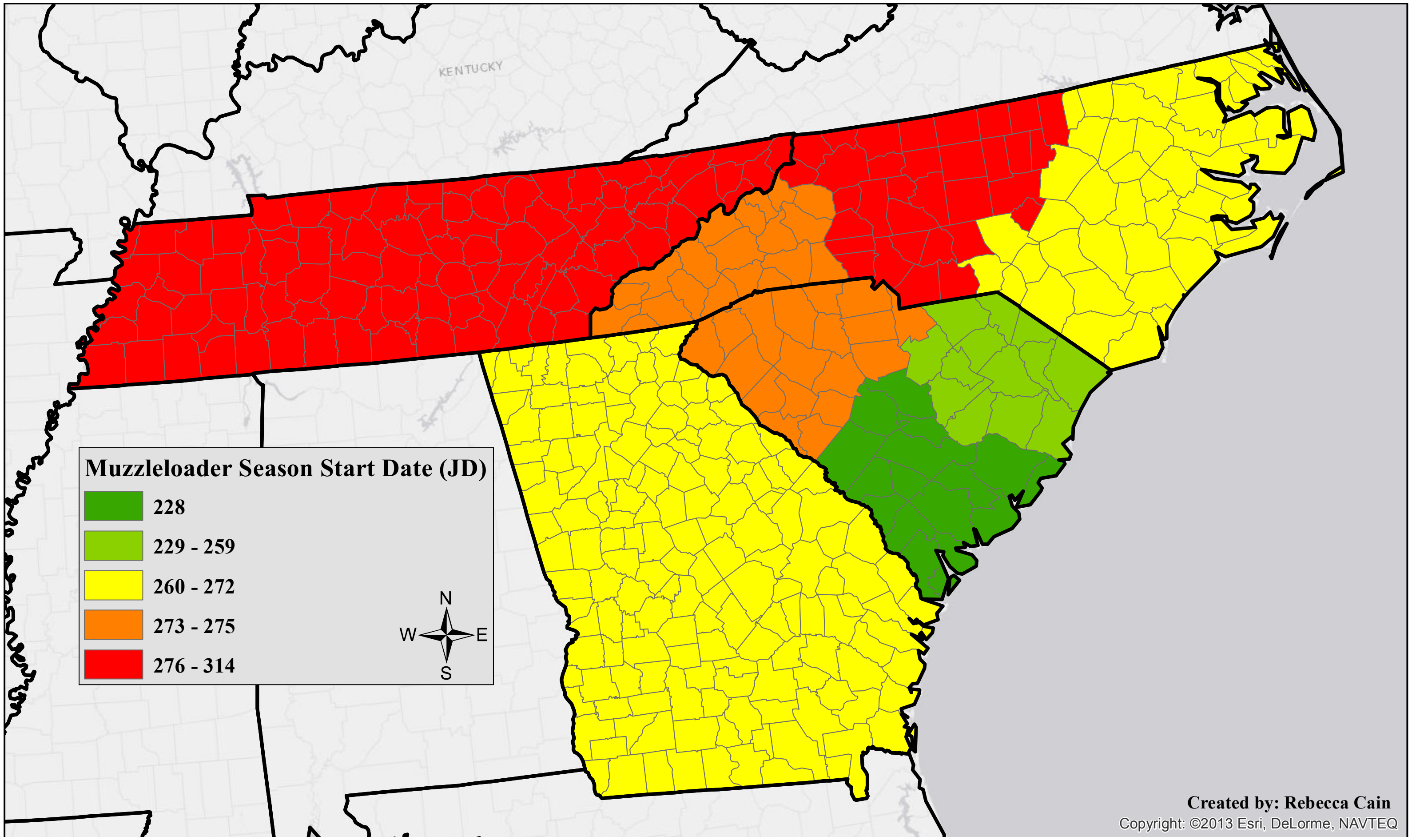

Figure 4.15: Map Displaying Muzzleloader Season Start Dates (Julian Date) for each county in Georgia, North Carolina, South Carolina, and Tennessee

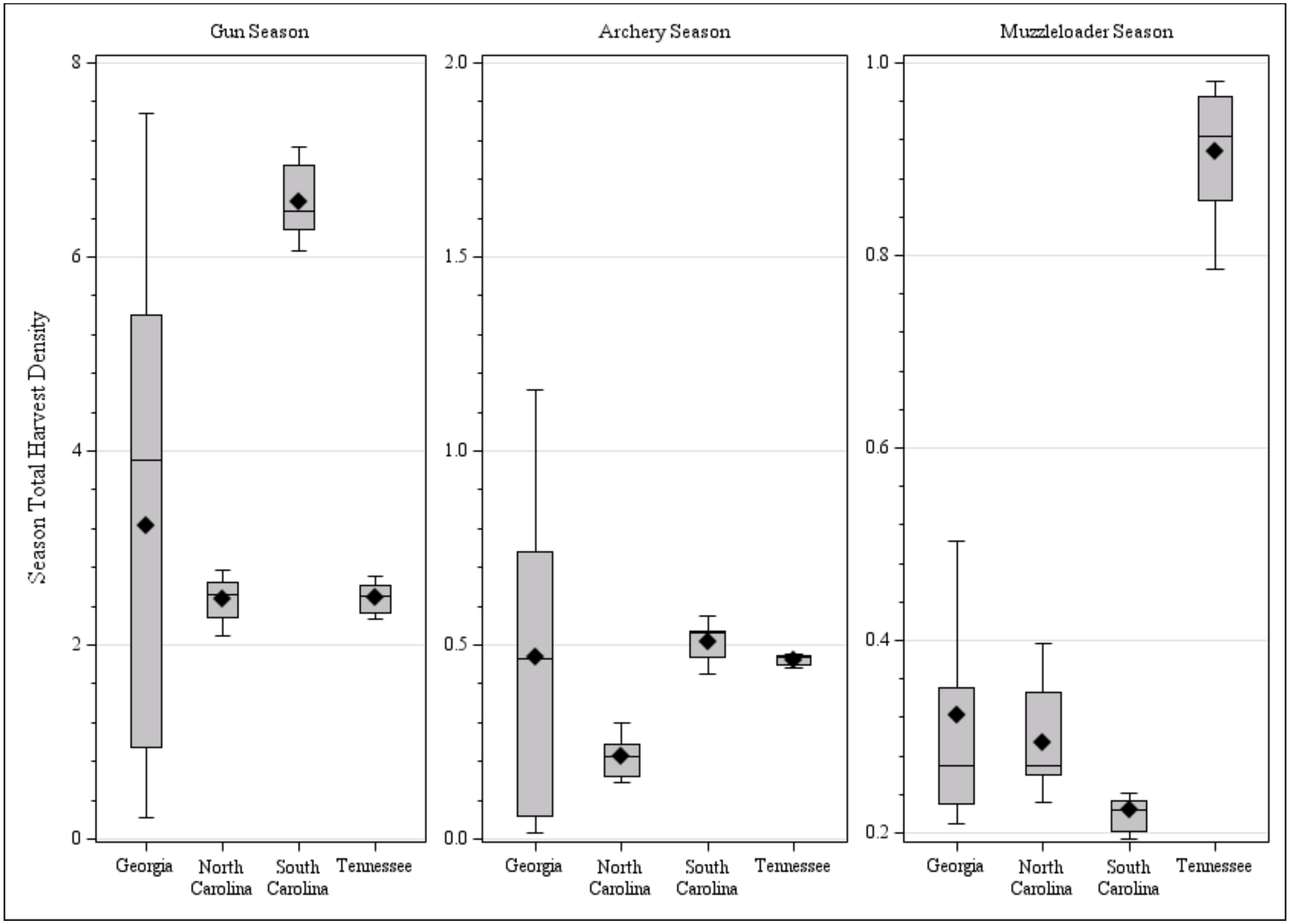

Figure 4.16: Harvest Density (deer/mi^2) for Each Hunt Type by State

CHAPTER FIVE

HUNTER EFFORT & HUNTER NUMBER CORRELATIONS

5.1 COUNTY LEVEL DATA

There is a significant correlation between hunter effort and total harvest, as well as between the number of hunters and total harvest ($p<0.0001$) at the county level (Table 5.1). The Spearman correlation coefficient is larger for hunter effort ($r=0.71$) than for total number of hunters ($r=0.52$) for total harvest at the county level. This mean that as the hunter effort or the number of hunters increases, so does the predicted total harvest (Figure 5.1).

When analyzing the correlation between hunter effort and doe harvest as well as the correlation between the number of hunters and doe harvest, both are significant ($p<0.0001$) at the county level. Again, the Spearman correlation coefficient is larger for hunter effort ($r=0.68$) than for total number of hunters ($r=0.55$) for doe harvest at the county level. This means that as the number of hunters or hunter effort increases, the predicted doe harvest also increases (Figure 5.2).

Buck harvest shows a significant correlation with hunter effort as well as with the number of hunters ($p<0.0001$) at the county level (Table 5.1). Once more, the Spearman correlation coefficient is larger for hunter effort ($r=0.68$) than for total number of hunters ($r=0.50$) for buck harvest at the county level. The predicted buck harvest shows the same trend as the total and doe harvest; as the number of hunters or the hunter effort increases, the predicted buck harvest also increases (Figure 5.3). The sample size for these correlations was 714 observations; therefore issues surrounding small sample sizes are not a concern for these correlations.

5.2 STATE LEVEL DATA

There is also a significant correlation between hunter effort and total harvest, as well as between the number of hunters and total harvest ($p<0.0001$) at the state level (Table 5.1). The Spearman correlation coefficient is much larger for hunter effort ($r=0.75$) than for total number of hunters ($r=0.39$) at the state level. This means that as the number of hunters or the hunter effort increases, the predicted total harvest is also expected to increase because of the positive correlation (Figure 5.1).

The analysis for doe harvest revealed that there is a significant correlation between hunter effort and doe harvest ($p<0.0001$), but not between the number of hunters and doe harvest ($p=0.3454$) at the state level (Table 5.1). The Spearman correlation coefficient is very large for hunter effort ($r=0.75$) and negative for total number of hunters ($r= -0.10$) at the state level. Therefore, as the number of hunters increases, there is no significant change in the predicted doe harvest, but as the hunter effort increases the predicted doe harvest is also expected to increase (Figure 5.2).

Alternatively, the analysis for buck harvest revealed that there is a significant correlation between the number of hunters and buck harvest ($p=0.0006$), but not between hunter effort and buck harvest ($p=0.64$) at the state level (Table 5.1). Additionally, the Spearman correlation coefficient is negative for both correlations of buck harvest, and the magnitude of the coefficient for the number of hunters ($r= -0.37$) is larger than the magnitude for hunter effort ($r= -0.06$) at the state level. Therefore, as the number of hunters increases, the predicted buck harvest is expected to decrease. Also, as hunter effort increases, there is no significant change in the predicted buck harvest (Figure 5.3). The smallest sample size for the correlations at the state-level was 55 observations; therefore a small sample size was not a concern.

5.3 HUNTING SEASON CHANGES AND IMPACT ON MEAN TOTAL EFFORT

An examination of the odds ratio and confidence intervals for the hunting season start dates and percent habitat suggests that the archery season start date is not a significant predictor for total effort when the other regressor are held constant (Figure 5.4) The vertical blue, dotted line symbolizes where the odds ratio is equal to one. Because the confidence interval for the archery season start date contains OR=1 (i.e. crosses the blue dotted line), I can conclude that the archery season start date is not significant (Odds Ratio [OR]=1.0025; 95% Confidence Interval: 0.9980, 1.0069). This observation is supported by the high p-value archery season start date received when the regression was run (p-values and chi-squared values are in Table 5.2). The gun season start date is significant and shows a negative relationship with total effort with its odds ratio being less than one (Figure 5.4; 7.1% decrease in total effort for every 1 day later in the year the gun season starts; OR=0.9929; 95% Confidence Limit [CL]: 0.9903, 0.9955). Conversely, the muzzleloader season start date demonstrates a significant positive relationship with total effort (6.6% increase in total effort for every 1 day later in the year the muzzleloader season starts; OR=1.0066; 95% CL: 1.0029, 1.0102). Percent predicted deer habitat in the county also shows a significant positive relationship with total effort (2.51% increase in total effort for every 1% increase in percentage of predicted deer habitat in the county; OR=1.0251; 95 % CL: 1.0219,1.0283).

An examination of the odd ratio and confidence intervals for the variables used to model total effort by hunting season lengths and percent habitat suggests the archery season length and muzzleloader season length are not significant predictors of hunter effort when the other regressor in the model are held fixed (Figure 5.5). Once again, the vertical blue, dotted line symbolizes where the odds ratio is equal to one. Confidence intervals occurring entirely to the right of the dotted line show a positive significant relationship with total effort, and any confidence intervals entirely to the left have a significant negative relationship with total effort. The archery season length is insignificant, because the orange colored symbol extends over this vertical dotted line (Figure 5.5; OR=0.999; 95% Confidence Interval: 0.9942, 1.0038). Additionally, the olive-green symbol that represents the muzzleloader season length crosses the dotted line, thus the muzzleloader season length is also insignificant (Figure 5.5; OR=0.9992; 95% CL: 0.9938, 1.0047). Both of these interpretations of the line plot (Figure 5.5) are supported by high, non-significant p-values obtained when the regression on the data was preformed (p-values and chi-squared values are in Table 5.2). As a result, gun season length is the only season length that is a significant predictor for total effort, having a positive relationship with total effort (0.45% increase in total effort for every 1 day increase in gun season length; OR=1.0045; 95% CL: 1.0016, 1.0074). Furthermore, the percent of predicted deer habitat in the county shows a significant positive relationship with total effort (Figure 5.5; 2.82% increase in total effort for every 1% increase in percentage of predicted deer habitat in the county; OR=1.0282; 95 % CL: 1.0252,1.0313).

5.4 CHAPTER FIVE CONCLUSIONS

When wildlife managers estimate the number of hunters for a given species, they look at the sales for the type of license that hunters would need. This can be a fairly rough measure of hunter numbers because hunters typically do not have to buy a special license for white-tailed deer. Consequently deer managers can only determine how many hunters have the legal standing to hunt/harvest white-tailed deer and cannot determine how many were actually actively hunting during the season.

Both total and doe harvests are more highly correlated with hunter effort than the number of hunters. The positive correlations between hunter effort and total/doe harvest are seen at both the county- and state-level. This outcome makes intuitive sense because a state could have an extremely large number of hunters in general, but if none of them actively sought a certain species, in this case deer, the harvest data is going to be much smaller than you would expect if you used the number of hunters to estimate harvest. Additionally, the rate of increase is greater for hunter effort than the rate of increase for the number of hunters. Therefore deer managers should strive to increase hunter effort because it would more effectively increase doe harvest. To increase hunter effort, deer managers should open access to habitat for deer hunters wherever feasible, as well as monitor the hunter satisfaction of their area.

The correlations between buck harvest with the number of hunters and hunter effort differ from the total and doe correlations at the state level. The buck harvest is actually more correlated with the number of hunters than hunter effort, and the buck harvest vs. number of hunters' correlation is negative. This means that as the number of hunters increases, the correlation suggests there will be a decrease in predicted buck harvest. Additionally, increases in hunter effort are not expected to show a significant change in the predicted buck harvest. Deer managers should still strive to increase hunter effort in areas where the goal is to decrease the population size, because increasing the effort is predicted to increase the doe harvest, thus lowering the population growth without significantly affecting the predicted buck harvest at the state level.

The correlations between buck harvest vs. hunter effort and the number of hunters at the county level share an analogous pattern demonstrated by the total and doe harvest correlations at the county level. Buck harvest is more highly correlated with hunter effort than the total number of hunters at the county level. However the Spearman correlation coefficients are slightly smaller for buck harvest than the total and doe harvests vs. hunter effort and the number of hunters. This means that changes in hunter effort and the number of hunters will have a lesser impact on the predicted buck harvest at the county level. Conversely, the Spearman correlation coefficients are greatest for doe harvest than the total and buck harvests vs. hunter effort and the number of hunters. Thus changes in hunter effort and the number of hunters will show the greatest impact in the predicted doe harvest.

Altering the lengths and timing of the first day of a hunting season for each of the hunting seasons is a way that deer managers could increase hunter effort. According to the season start date model, deer managers can begin gun season earlier or start muzzleloader season later in the year to increase total effort. From both of these total effort models, it would appear that managers should not worry over when to start archery season or its duration, because archery season start date and length were not significant predictors of total effort. According to the model results, another way to increase total effort would be to increase the length of the gun season. Although the muzzleloader season start date is correlated with total effort, the muzzleloader season length is not, so as long as you push the muzzleloader season start date to slightly later in the year the model predicts an increase in total effort. The percent changes in total effort are the highest for the gun and muzzleloader season start dates; therefore deer managers should be more cautious when altering the timing of the season starts dates because they have a greater influence on total hunter effort.

It should be noted that these predicted changes in total effort in response to changes in hunting season start dates and lengths make several assumptions about hunter behavior. This assumes, for example, that hunters will behave exactly the same way every year and that they will have the same reaction to different degrees of changes in hunting seasons. In other words they will put forth the same amount of effort when a season starts ten days later than the current start date as they will when a season starts one day later than the current start date. Furthermore hunter effort should be viewed as a minimum, because the variable only takes into account the total number of days spent hunting. If a hunter goes into the field several times during a single day, hunter effort is still recorded as one day. Measuring hunter effort by days is probably very accurate, but the measurement is not precise. A better measure of hunter effort could be the number of hours hunters spend hunting. However, where hunters might remember the number of days, it might be more difficult for them to remember the number of hours they spend hunting during a season. Despite how you measure hunter effort, increasing this value should be a main theme for deer managers, especially in areas where hunter retention is not very high.

5.5 CHAPTER TABLES

Table 5.1: Spearman Correlation Coefficients and p-values for total harvest density (deer/mi^2), doe harvest density (deer/mi^2), and buck harvest density (deer/mi^2) with hunter number density (hunters/mi^2) and hunter effort density (days hunted/mi^2) at the state and county levels.

	County		State	
	Number	Effort	Number	Effort
Total Harvest	0.52050 p<0.0001	0.70173 p<0.0001	0.39893 p<0.0001	0.75443 p<0.0001
Doe Harvest	0.53316 p<0.0001	0.71029 p<0.0001	-0.10361 p=0.3454	0.75361 p<0.0001
Buck Harvest	0.50177 p<0.0001	0.68373 p<0.0001	-0.36545 p=0.0006	-0.06447 p=0.6400

Table 5.2: Chi^2 and p-values for the variables in the models predicting total hunter effort by hunting season start dates (Julian Date) and season lengths (days)

	Season Start Dates		Season Lengths	
Source	Chi^2	P-value	Chi^2	P-value
Gun	27.89	<0.0001	9.45	0.0021
Archery	1.20	0.2726	0.17	0.6766
Muzzleloader	12.54	0.0004	0.07	0.7855
Percent Habitat	237.37	<0.0001	338.9	<0.0001

5.6 CHAPTER FIGURES

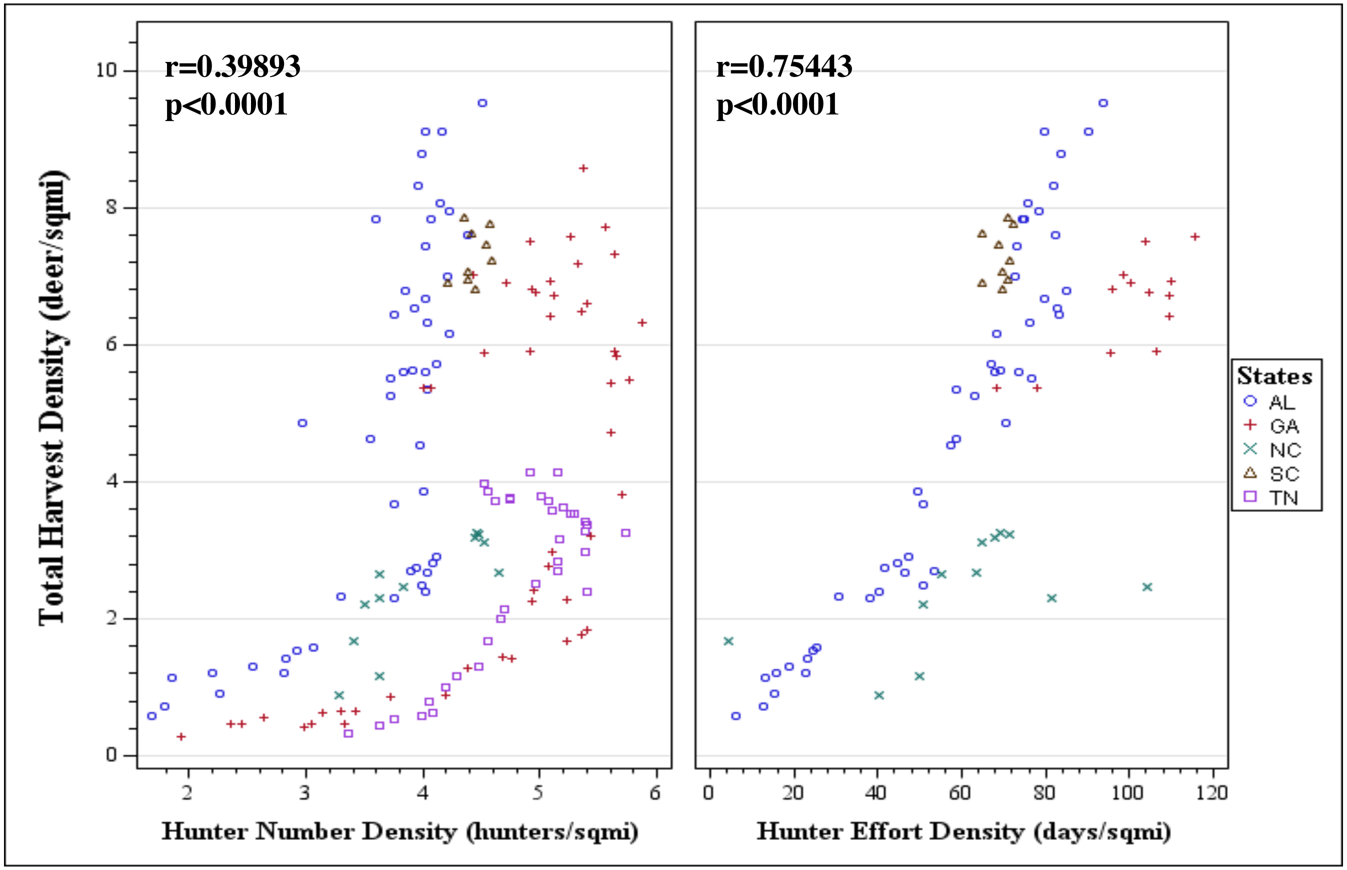

Figure 5.1: Scatter plots for total harvest density (deer/mi^2) with hunter number density (hunters/mi^2) and hunter effort density (days/mi^2)

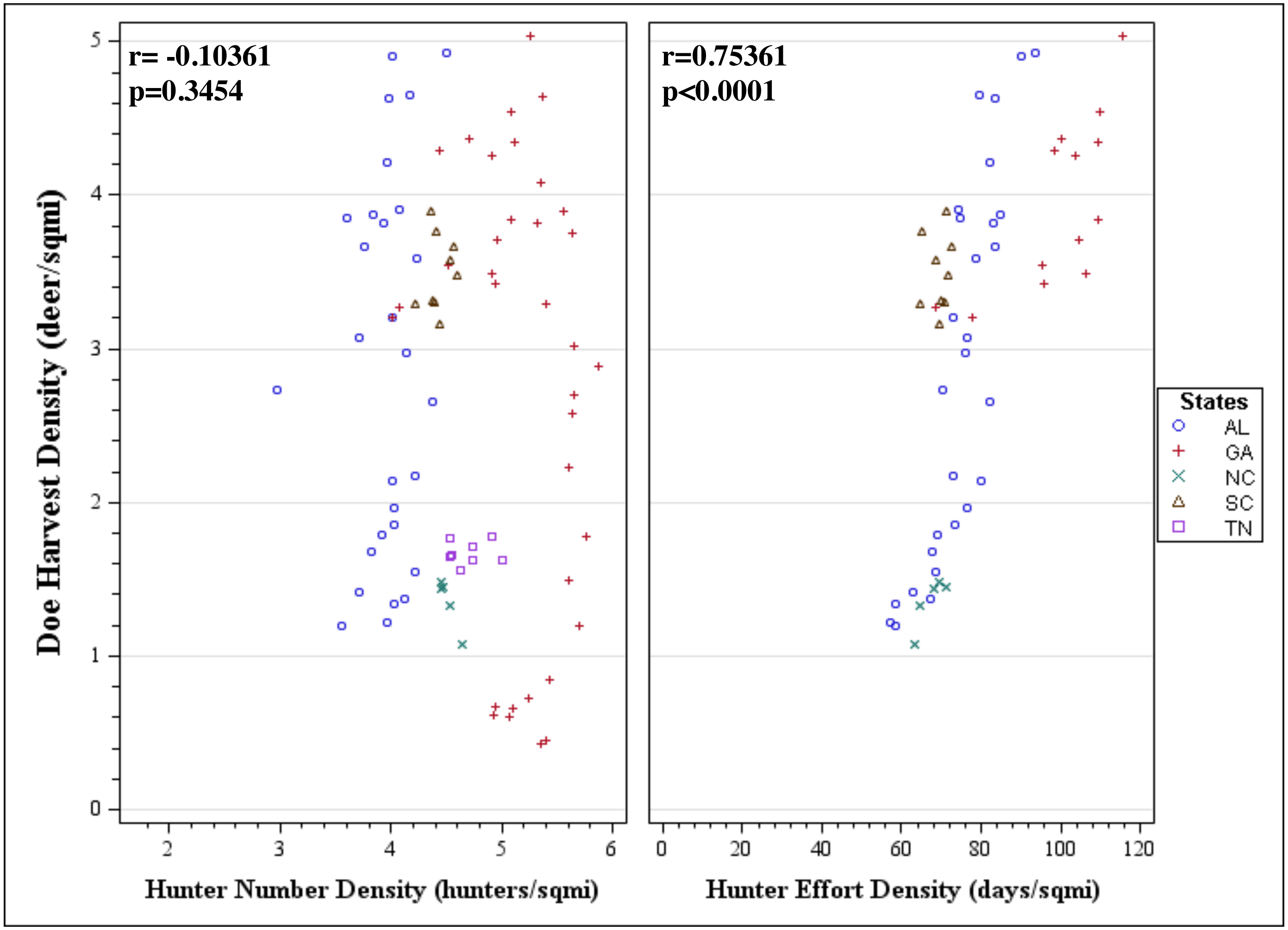

Figure 5.2: Scatter plots for doe harvest density (deer/mi^2) with hunter number density (hunters/mi^2) and hunter effort density (days/mi^2)

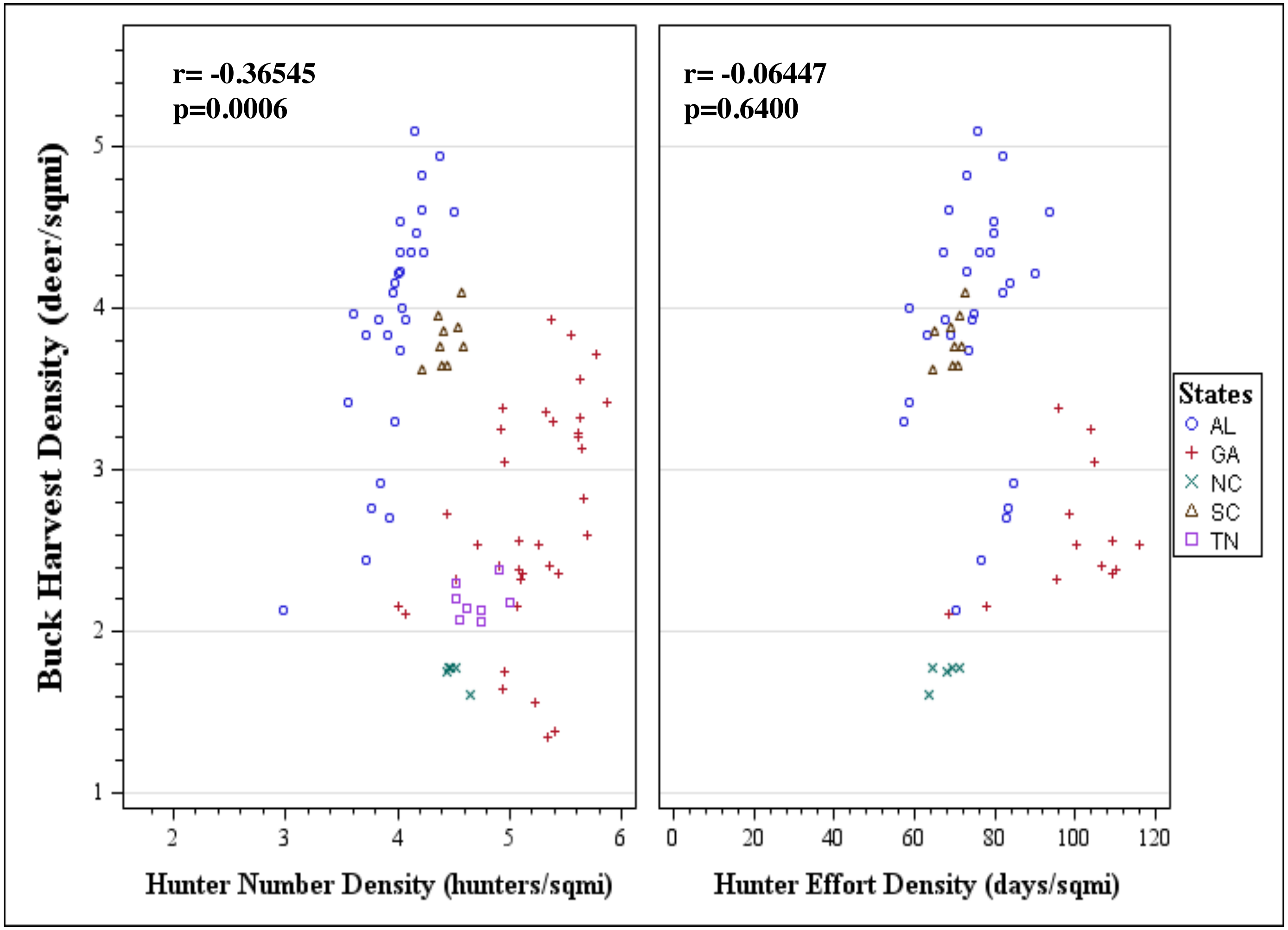

Figure 5.3: Scatter plots for buck harvest density (deer/mi^2) with hunter number density (hunters/mi^2) and hunter effort density (days/mi^2)

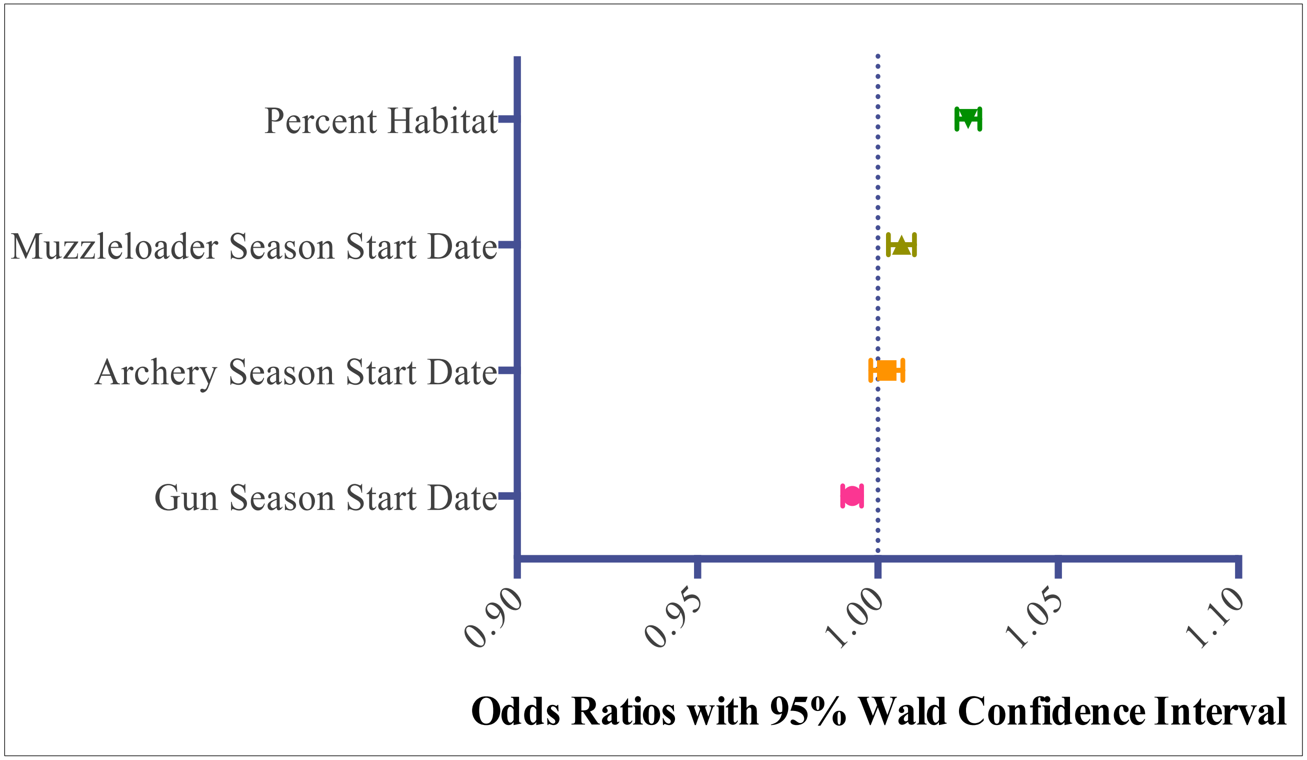

Figure 5.4: Odds ratio and corresponding confidence intervals for the hunting season start date and percent habitat variables of the total effort (days) by season start date model (the dotted line is at OR=1)

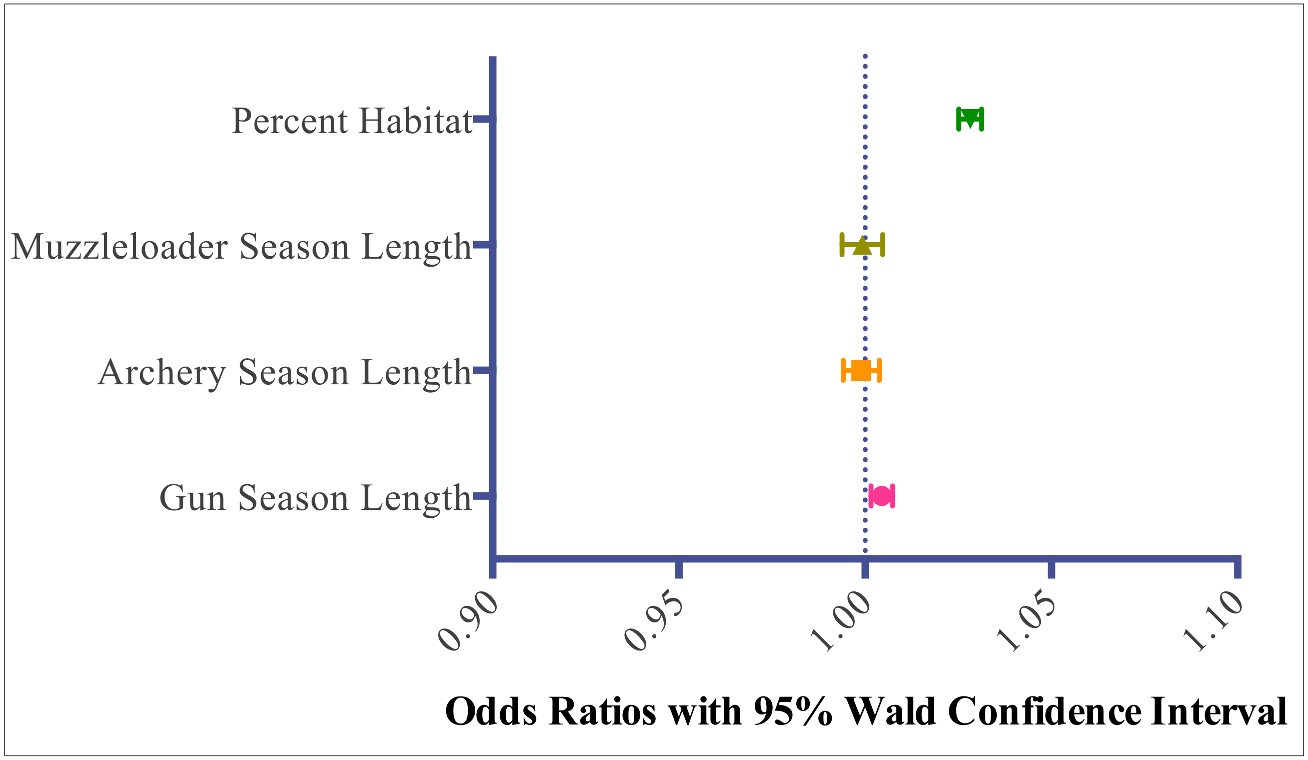

Figure 5.5: Odds ratios and corresponding confidence intervals for the hunting season length and percent habitat variables of the total effort (days) by season length model (the dotted line is at OR==1)

CHAPTER SIX

NONRESIDENT & RESIDENT HUNTER RESPONSE TO DIFFERENT HUNTING SEASONS

6.1 SEASON START DATES & NONRESIDENT HUNTER NUMBER

For the number of nonresident hunters, all of the season start dates are significant (Table 6.1, Figures 6.1-6.3). There is also a significant relationship between the number of nonresident hunters and the distance between the closest state boarder and the county's geometric mean (Figure 6.4; 4.12% decrease in the number of nonresident hunters for every 1-unit increase in distance; OR: 0.9588; 95% confidence limits [CL]: 0.9421, 0.9758). Muzzleloader season start date also shows a significant, negative relationship with the number of nonresident hunters (Figure 6.4; 11.69% increase in the number of nonresident hunters for every 1 day earlier the muzzleloader season starts; OR: 0.0.8831; 95% CL: 0.8417, 0.9265). However, gun season start date shows a positive, significant relationship with the number of nonresident hunters (Figure 6.4; 6.81% increase for every 1 day later the gun season starts; OR: 1.0681; 95% CL: 1.0165, 1.1222. Archery season start date also shares a positive, significant relationship with nonresident hunters (Figure 6.4; 5.9% increase in the number of nonresident hunters for every 1 day later the archery season starts; OR: 1.0590; 95%CL: 1.024, 1.0951).

6.2 SEASON LENGTHS & NONRESIDENT HUNTER NUMBER

Moving from the season start date model to the model predicting the number of nonresident hunters using hunting season lengths, I will be able to show how the length of each hunting season influences the predicted number of nonresident hunters in a county (Figures 6.5-6.7).

When modeling the number of nonresident hunters for the season lengths, the archery season length is not significant (Figure 6.8; OR: 0.9944; 95%CL: 0.9613, 1.0285; a confidence interval spanning 1 indicates a lack of relationship in negative binomial regression model; Table 6.1). Once more, the relationship between county distance from the border and the number of nonresident hunters is significant and negative (Figure 6.8; 5.4% decrease in the number of nonresident hunters for every 1-unit increase in distance; OR: 0.9460; 95%CL: 0.9298, 0.9624). Gun season length (Figure 6.8; 12.42% decrease in nonresident deer hunters for every 1 day increase in gun season length; OR: 0.8758; 95% CL: 0.8373, 0.9160) shows a negative significant relationship with the number of nonresident hunters. Conversely, muzzleloader season length (Figure 6.8; 18.72% increase in nonresident hunters for every 1 day increase in muzzleloader season length; OR: 1.1872; 95% CL: 1.1370, 1.2397) shows a positive significant relationship with nonresident hunter number (Table 6.1).

6.3 SEASON START DATES & RESIDENT HUNTER NUMBER

For the number of South Carolina resident hunters, all of the season start dates are significant (Table 6.2, Figures 6.9-6.11). There is also a significant relationship between the number of resident hunters and the distance between the closest state boarder and the county's geometric mean (Figure 6.12; 3.4% increase in the number of resident hunters for every 1-unit increase in distance; OR: 1.0349; 95% confidence limits [CL]: 1.029, 1.0409). Muzzleloader season start date also shows a significant, negative relationship with the number of resident hunters (Figure 6.12; 5.52% decrease in the number of resident hunters for every 1 day later the muzzleloader season starts; OR: 0.9448; 95% CL: 0.929, 0.9608). However, gun season start date shows a positive, significant relationship with the number of resident hunters (Figure 6.12; 4.36% increase for every 1 day later in the year the gun season starts; OR: 1.0436; 95% CL: 1.0260, 1.0615). Archery season start date also shares a positive, significant relationship with resident hunters (Figure 6.12; 1.47% increase in the number of resident hunters for every 1 day later in the year the archery season starts; OR: 1.0147; 95%CL: 1.0040, 1.0255). Because none of the confidence intervals for the different predictors pass over the dotted line where the odd ratio is one, I could conclude that all of the variables in this model are significant (Figure 6.12). All of the variables with confidence limits on the right side of the dotted line have positive relationships with the number of resident hunters, and all the confidence intervals entirely to the left represent the variables with a negative relationship with the number of resident hunters (Figure 6.12).

6.4 SEASON LENGTHS & RESIDENT HUNTER NUMBER

Moving from the season start date model to the model predicting the number of South Carolina resident hunters using hunting season lengths, I will be able to show how the length of each hunting season influences the predicted number of South Carolina resident hunters in a county (Figures 6.13-6.15).

When modeling the number of resident hunters for the season lengths, the archery season length is not significant (Figure 6.16; OR: 0.9989; 95%CL: 0.9891, 1.0087; a confidence interval spanning 1 indicates a lack of relationship in negative binomial regression model; Table 6.1). The relationship between county distance from the border and the number of resident hunters is significant and positive (Figure 6.16; 3.18%

increase in the number of resident hunters for every 1-unit increase in distance; OR: 1.0318; 95%CL: 1.0259, 1.0378). Gun season length shows a negative significant relationship with the number of South Carolina resident hunters (Figure 6.16; 6.14% decrease in the number of resident deer hunters for every 1 day increase in gun season length; OR: 0.9386; 95% CL: 0.9238, 0.9536). Conversely, muzzleloader season length (Figure 6.16; 7.59% increase in resident hunters for every 1 day increase in muzzleloader season length; OR: 1.0759; 95% CL: 1.0589, 1.0932) shows a positive significant relationship with resident hunter number (Table 6.2).

6.5 CHAPTER SIX CONCLUSIONS

Visual representations of the number of resident and nonresident hunters for each county allows trends in hunter numbers to be appreciated with respect to the county's season start date and season length (Figures 6.1-6.3, 6.5-6.7, 6.9-6.11, & 6.13-6.15). The larger circles, indicating a greater number of nonresident hunters, occur along the South Carolina state border in areas where the season lengths and season start dates are dissimilar to adjacent states. An important note that although some of South Carolina's hunting seasons start dates occur later than others, the start dates for South Carolina are still earlier than the adjacent state (i.e. South Carolina's white-tailed deer herd is the earliest and closest game available for nonresident hunters in adjacent states).

However contrary to what I believed I was going to find, the positive relationship between the gun season start date and the number of nonresident hunters suggests that the later in the year these start dates occur, the greater the predicted number of nonresident hunters. Also, the negative relationship between muzzleloader season start date and the number of nonresident hunters suggests that a muzzleloader season starting earlier in the year shows an increase in the predicted number of out of state hunters. Only the archery season length was an insignificant variable in estimating the number of nonresident hunters in each county. The nonresident season lengths model predicts that a shorter gun season length or longer muzzleloader season length will result in an increased number of nonresident hunters.

Results of the analyses for both of the nonresident models suggest that hunting season lengths and season start dates do influence the number of nonresident hunters in a county. However, while a county's proximity to the state border also has an influence on the number of nonresident hunters, the influence of the distance variable on the predicted number of out-of-state hunters is much smaller than the influences of season lengths and start date.

Patterns involving the number of resident hunters (Figures 6.9-6.11 & Figures 6.13-6.15) in South Carolina are not as distinct as those for nonresidents (Figures 6.1- 6.3 & 6.5-6.7). It appears that there are fewer resident hunters in counties along the border where there were a lot of nonresident hunters (Figures 6.9-6.11). This resident pattern is opposite of what I noticed for the nonresident hunters. This differing pattern between the two groups of hunters makes sense because nonresident hunters are not likely to drive further into the state, especially if the bordering counties offer the same hunting opportunities (i.e. earlier opening days). The impact of the county's distance from the border is shown to be statistically significant for predicting the number of both resident and nonresident hunters. The number of nonresident hunters decreases as the distance from the border increases, while the number of resident hunters increases as the distance from the border increases. The contrasting effect of distance for hunter numbers is the only variable in which the response by nonresidents and residents differs in the season length and season start date models.

Archery season length was not a significant predictor for the number of resident or nonresident hunters. The numbers of resident hunters and the numbers of nonresident hunters respond analogously, but at slightly different magnitudes, for all other variables in the hunting season lengths and the hunting season start dates models. Therefore, from these results I can conclude that changes in the hunting season parameters (start date and length) affect the predicted number of both resident and nonresident hunters in a similar way, with the only major difference being in the location of hunting activities.

These are important findings, especially if the hunting behaviors of nonresident hunters differ significantly from the hunting behavior of resident hunters. I believe a study focusing on the behaviors of resident and nonresident hunters is a crucial next step for determining if the two groups show significant differences in hunting behavior. Knowing how different variables are predicted to influence hunter behavior is a very important consideration for managers when they are developing white-tailed deer harvest goals.

It is also important to quickly note that the direction of influence by the different season parameters on the number of nonresident hunters were the opposite from the direction found for the total effort model in Chapter 5. The difference could be partially understood by knowing that the data for resident and nonresident hunter numbers only came from one state, South Carolina, and it is the state with the most liberal hunting regulations. Intuitively the results regarding hunter effort (summarized in Chapter 5) made sense, however when analyzing the Chapter 6 results I found the opposite of what I was expecting. I believe the inclusion of resident and nonresident hunter data from other states in the model would help determine if this Chapter's results are specific to South Carolina, or are more broadly applicable to other area in the Southeast.

6.6 CHAPTER TABLES

Table 6.1: Chi[3] and p-values for the hunting season start dates (Julian Date), season lengths (days), and county distance from closest boarder (miles) in nonresident hunter number models

	Season Start Dates		Season Lengths	
Source	Chi^2	P-value	Chi^2	P-value
Gun	6.81	0.0091	33.53	<0.0001
Archery	11.21	0.0008	0.11	0.7425
Muzzleloader	25.77	<0.0001	60.52	<0.0001
Distance	22.08	<0.0001	40.13	<0.0001

Table 6.2: Chi^2 and p-values for the hunting season start dates (Julian Date), season lengths (days), and county distance from closest boarder (miles) in resident hunter number models

	Season Start Dates		Season Lengths	
Source	Chi^2	P-value	Chi^2	P-value
Gun	24.30	<0.0001	61.47	<0.0001
Archery	7.26	0.0070	0.05	0.8197
Muzzleloader	43.79	<0.0001	80.56	<0.0001
Distance	135.8	<0.0001	113.6	<0.0001

6.7 CHAPTER FIGURES

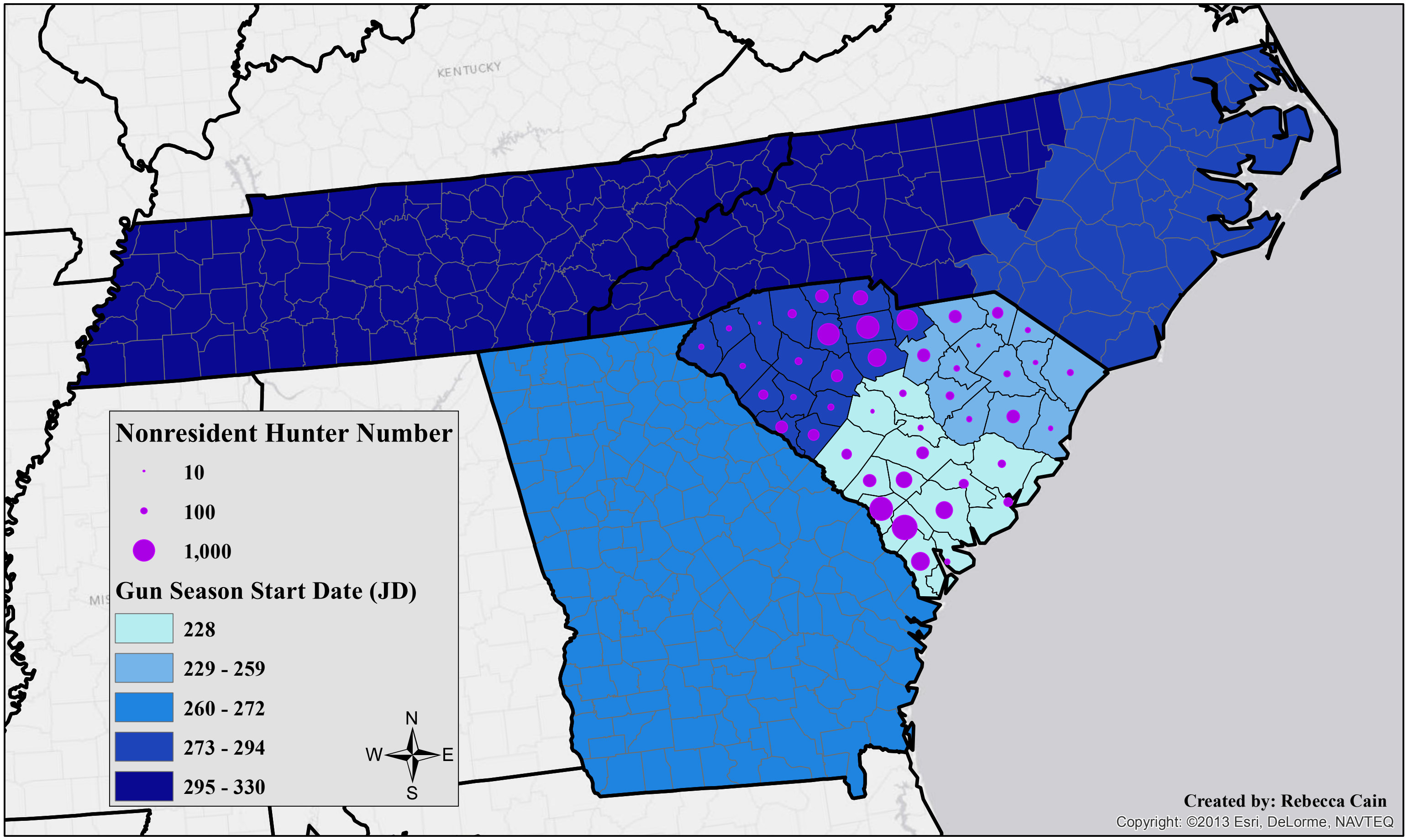

Figure 6.1: Map showing the gun season start dates as the Julian Date (JD) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of nonresident hunters for the South Carolina counties.

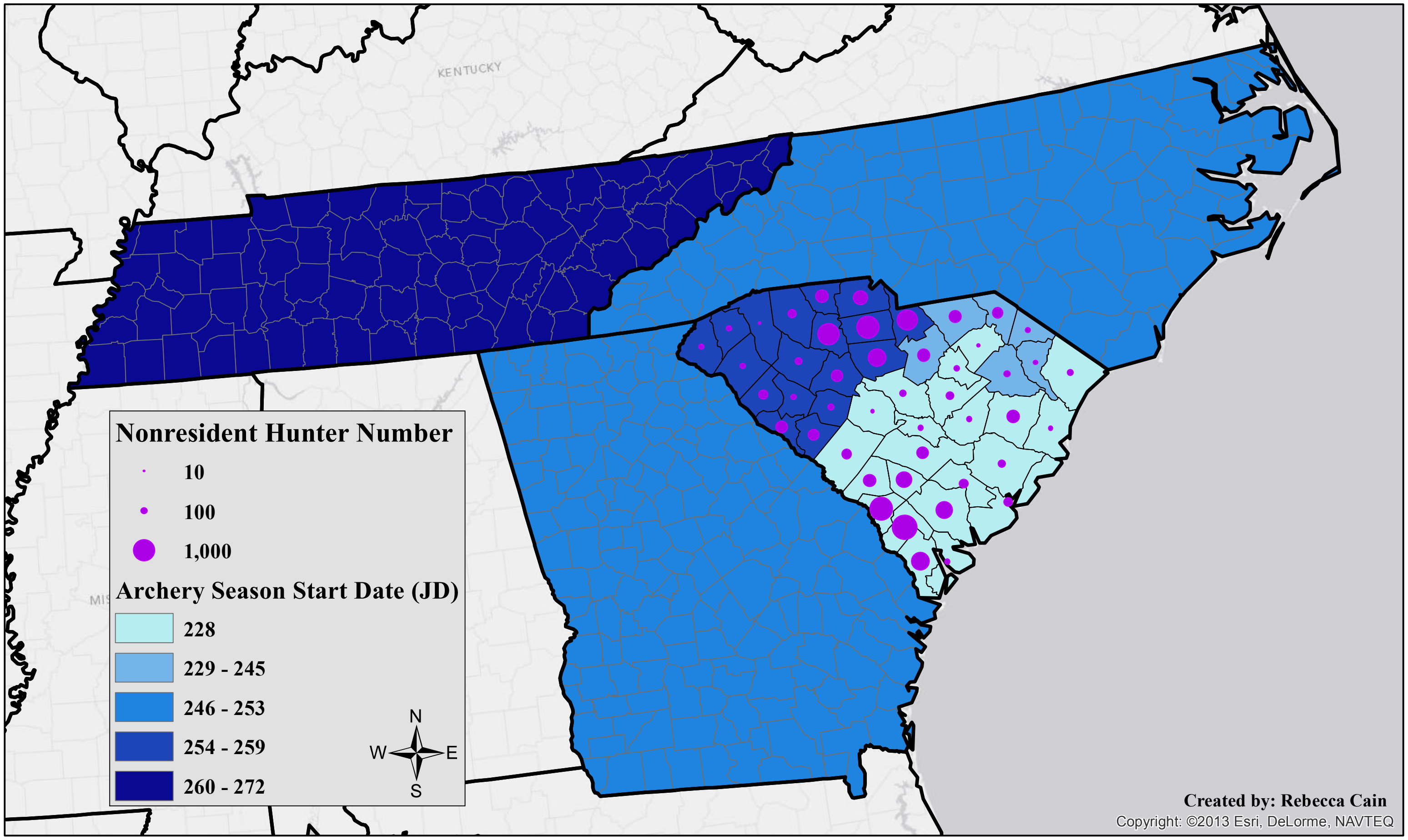

Figure 6.2: Map showing the archery season start dates as the Julian Date (JD) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of nonresident hunters for the South Carolina counties.

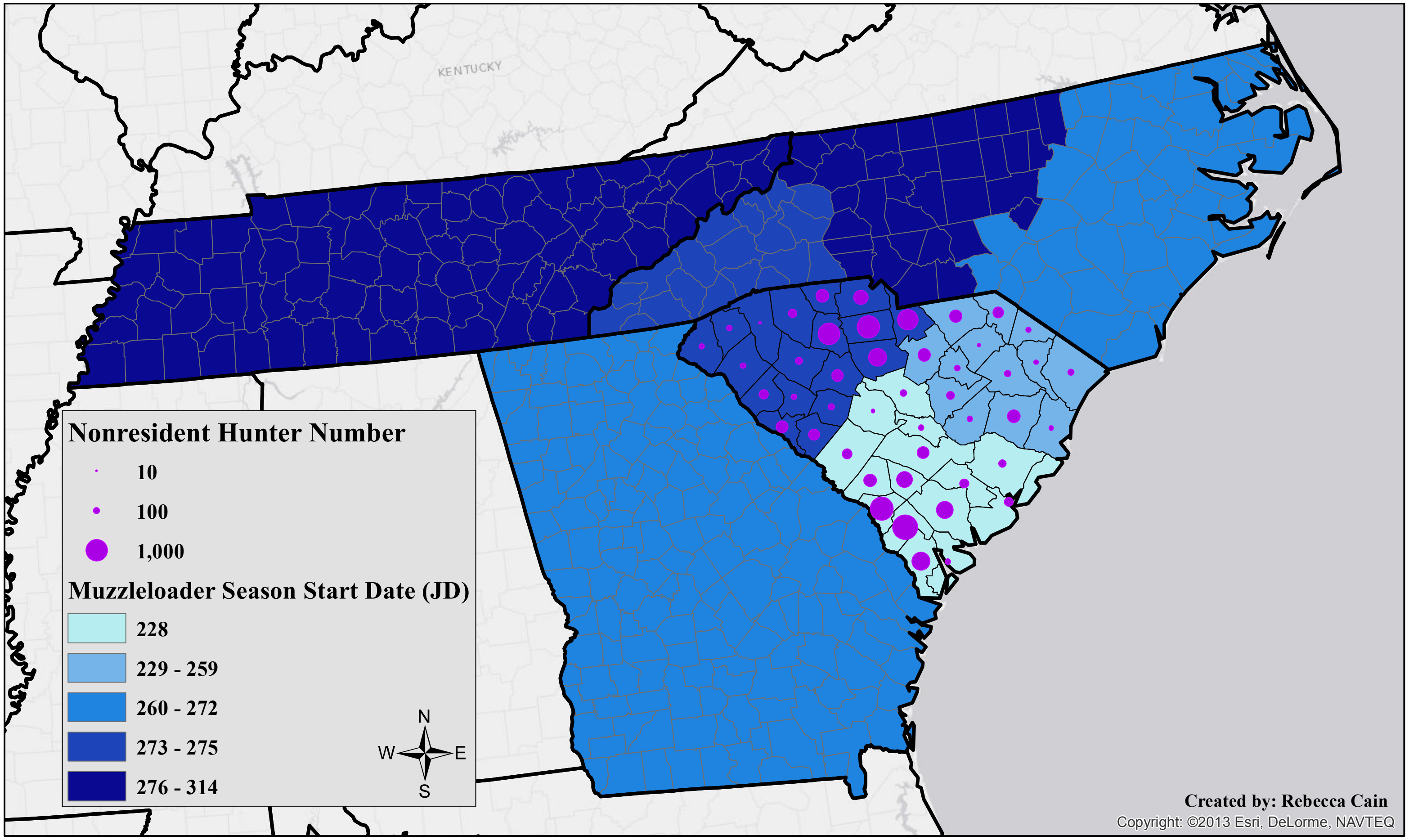

Figure 6.3: Map showing the muzzleloader season start dates as the Julian Date (JD) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of nonresident hunters for the South Carolina counties.

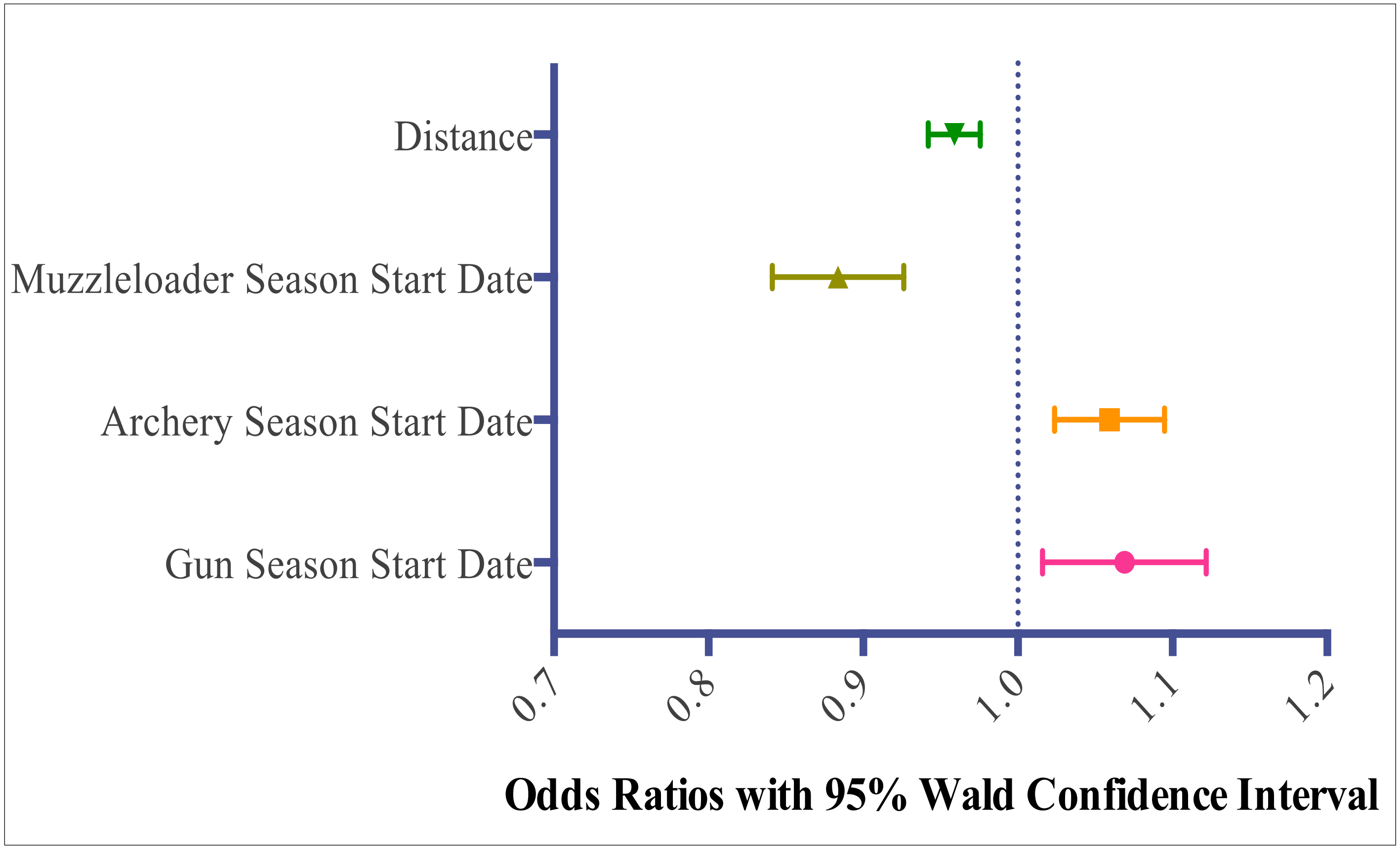

Figure 6.4: Odds ratio and corresponding confidence intervals for the independent variables from the nonresident hunter by season start date (Julian Date) model (the dotted line is at OR=1)

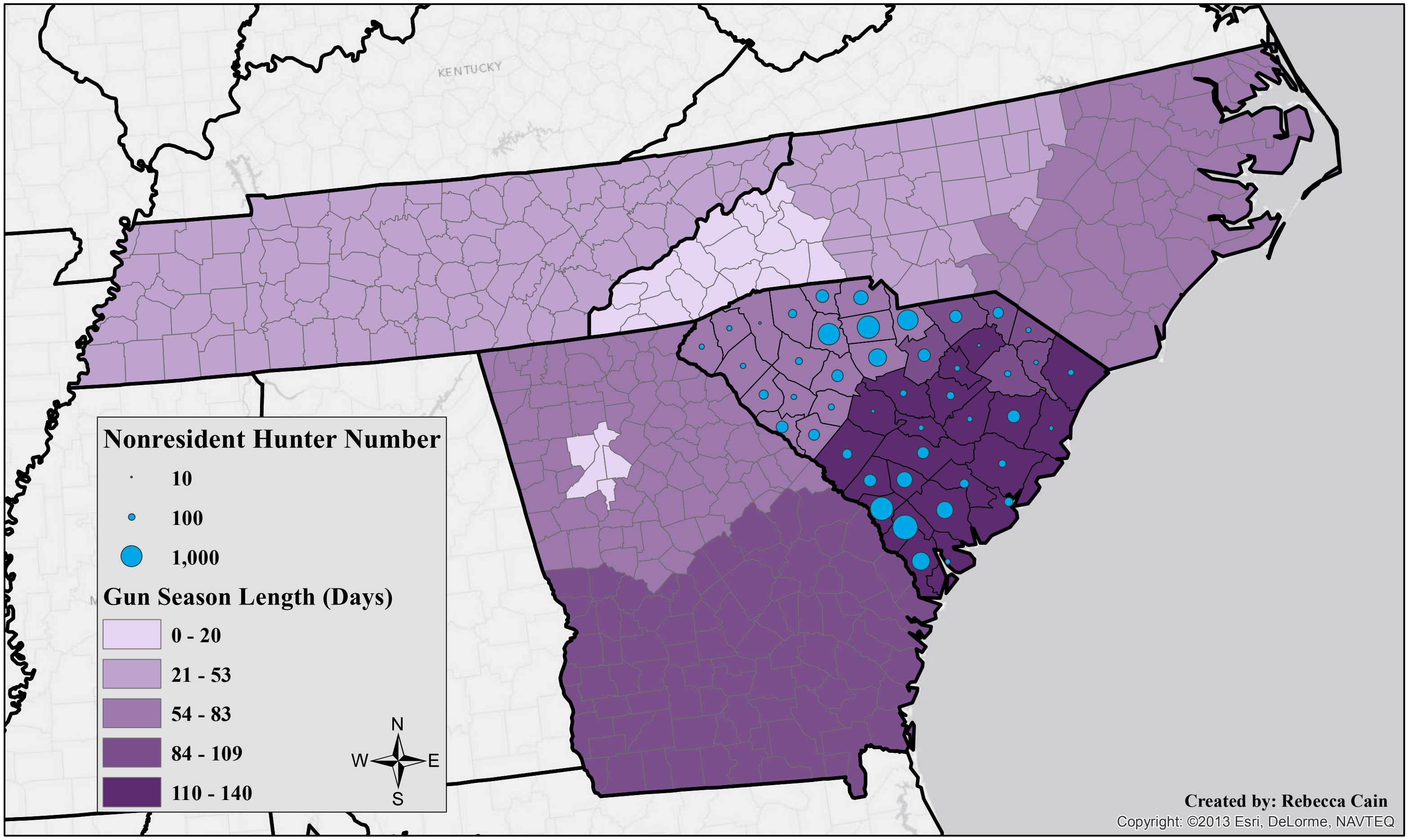

Figure 6.5: Map showing the gun season lengths (days) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of nonresident hunters for the South Carolina counties.

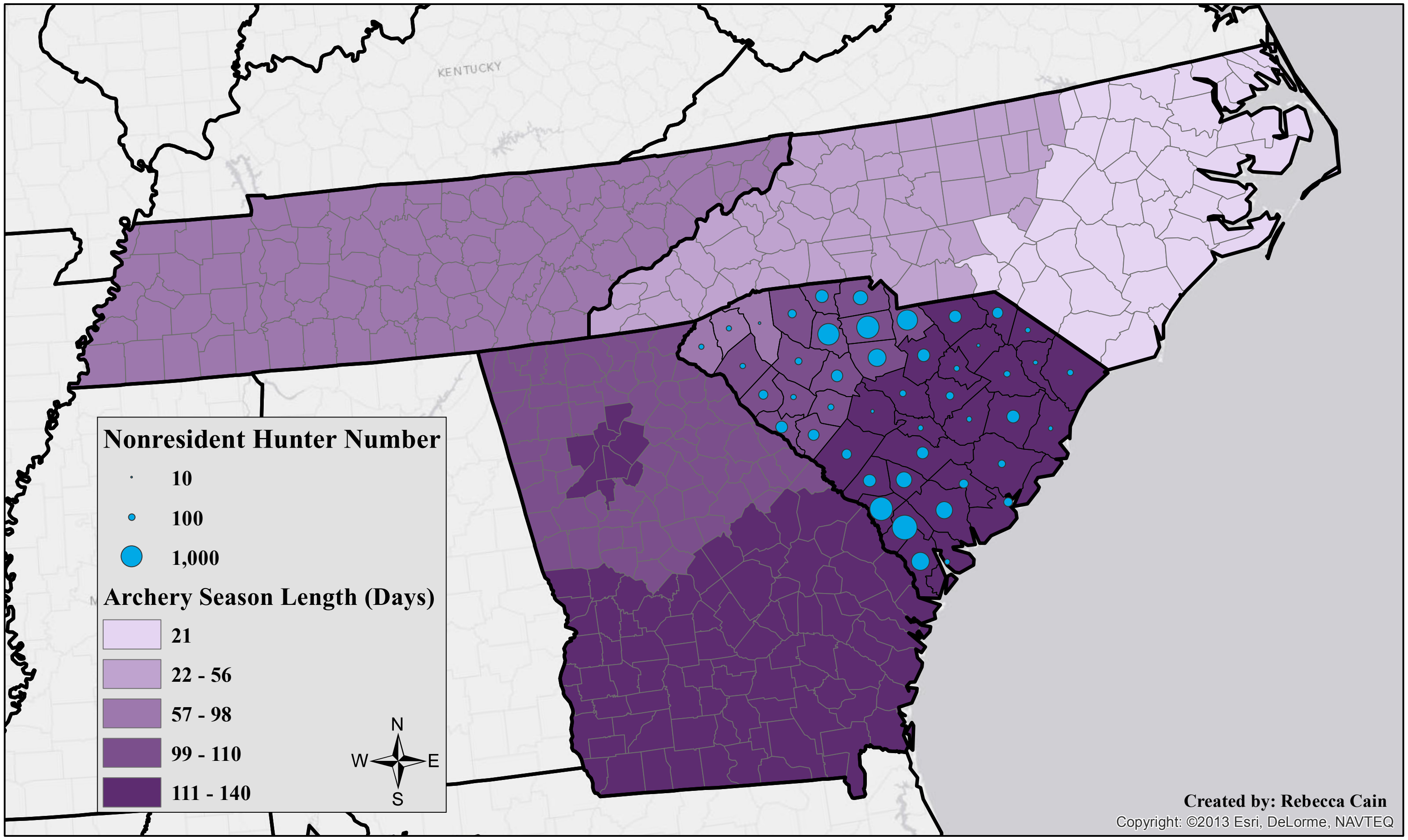

Figure 6.6: Map showing the archery season lengths (days) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of nonresident hunters for the South Carolina counties.

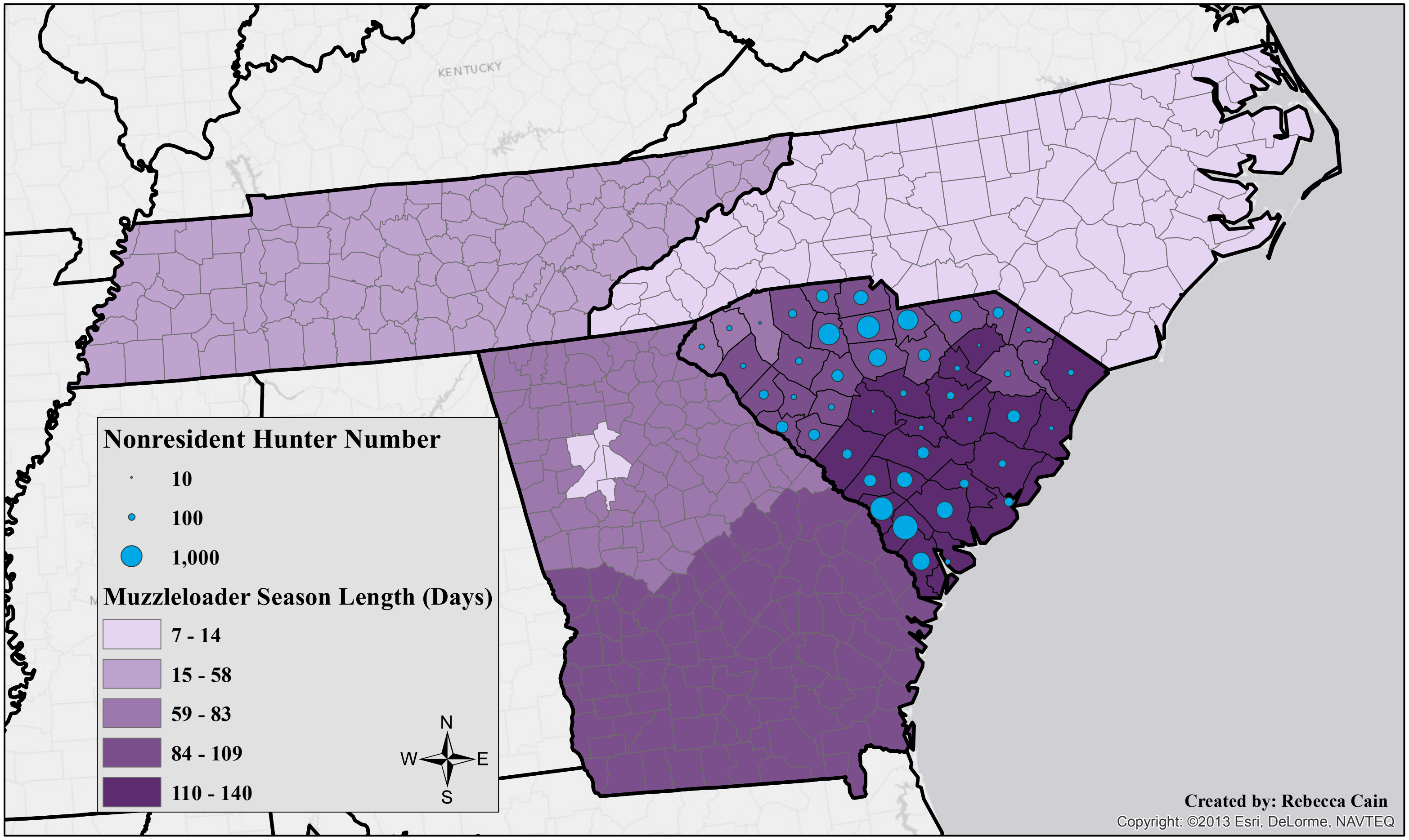

Figure 6.7: Map showing the muzzleloader season lengths (days) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of nonresident hunters for the South Carolina counties.

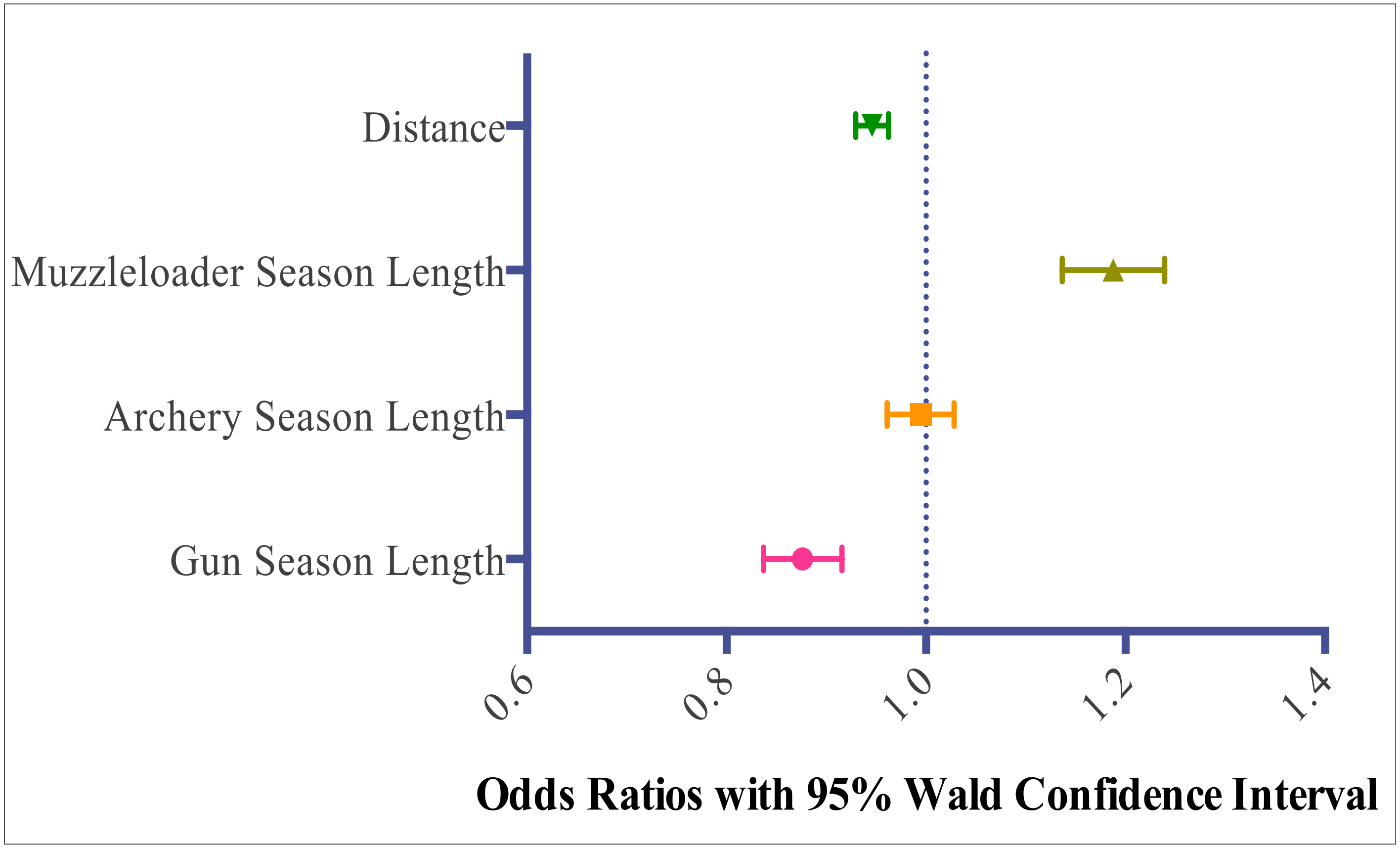

Figure 6.8: Odds ratio and corresponding confidence intervals for the independent variables from the nonresident hunter by season length (days) model (the dotted line is at OR=1)

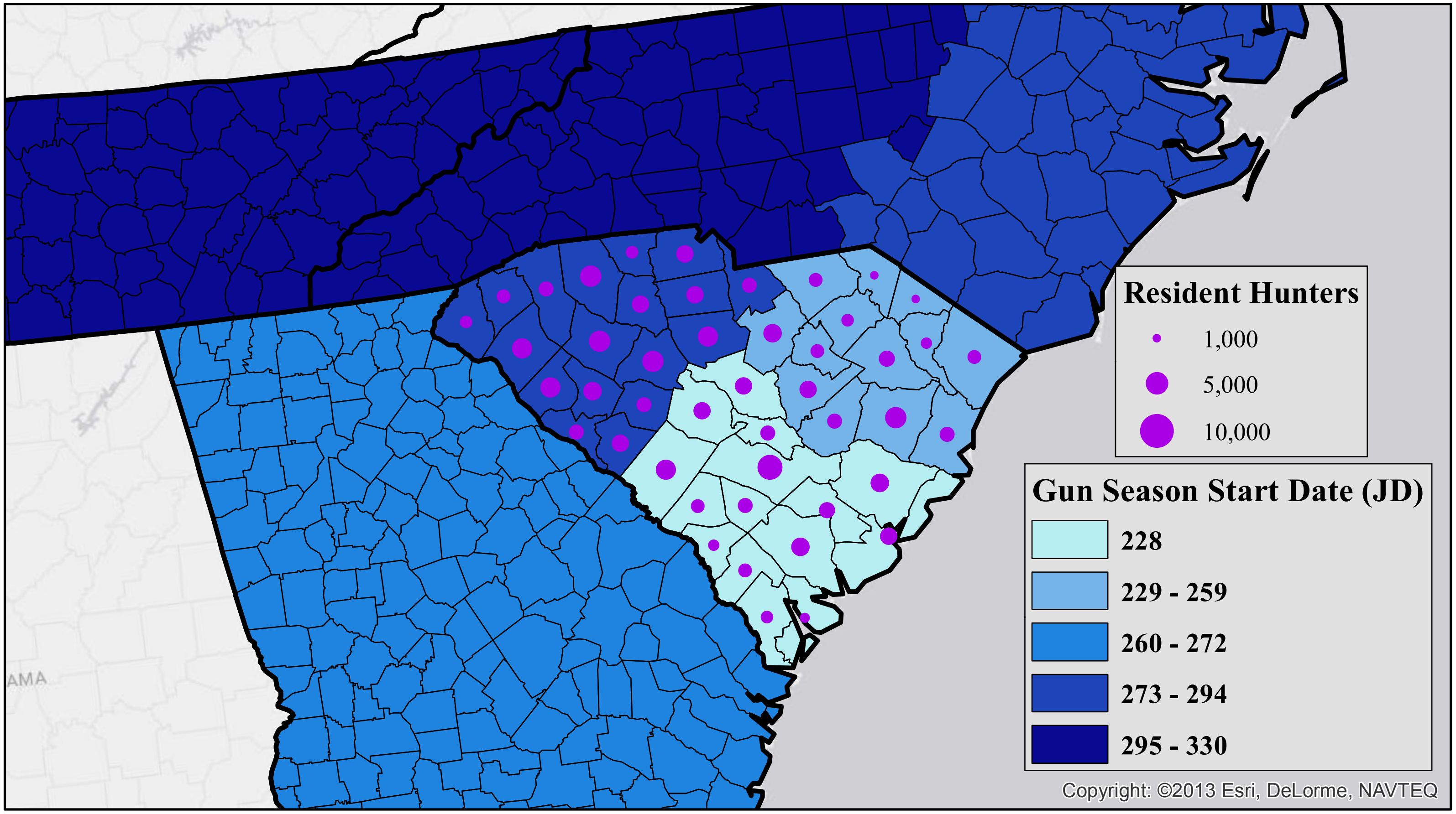

Figure 6.9: Map showing the gun season start dates as the Julian Date (JD) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of South Carolina resident hunters.

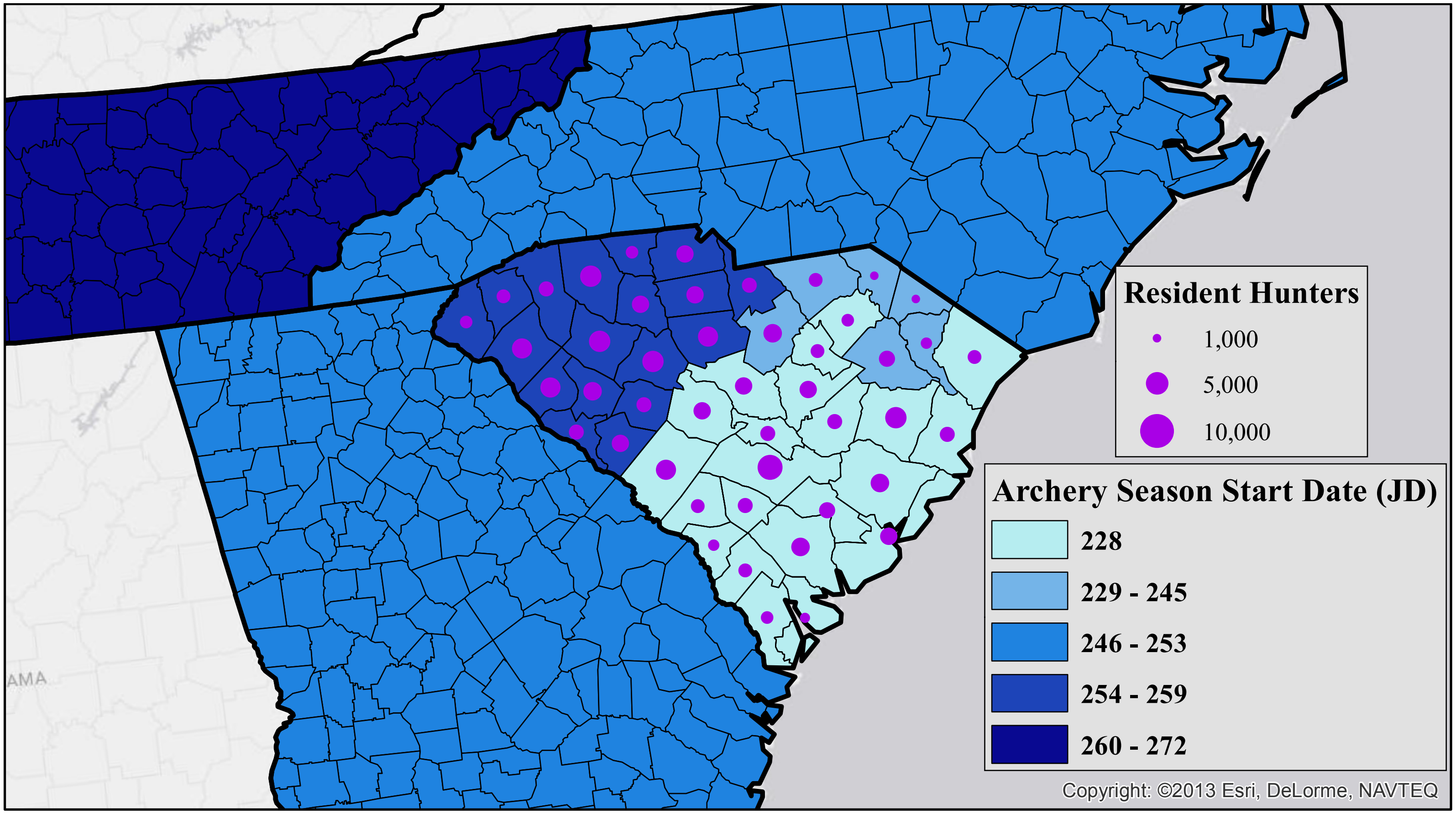

Figure 6.10 Map showing the archery season start dates as the Julian Date (JD) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of South Carolina resident hunters.

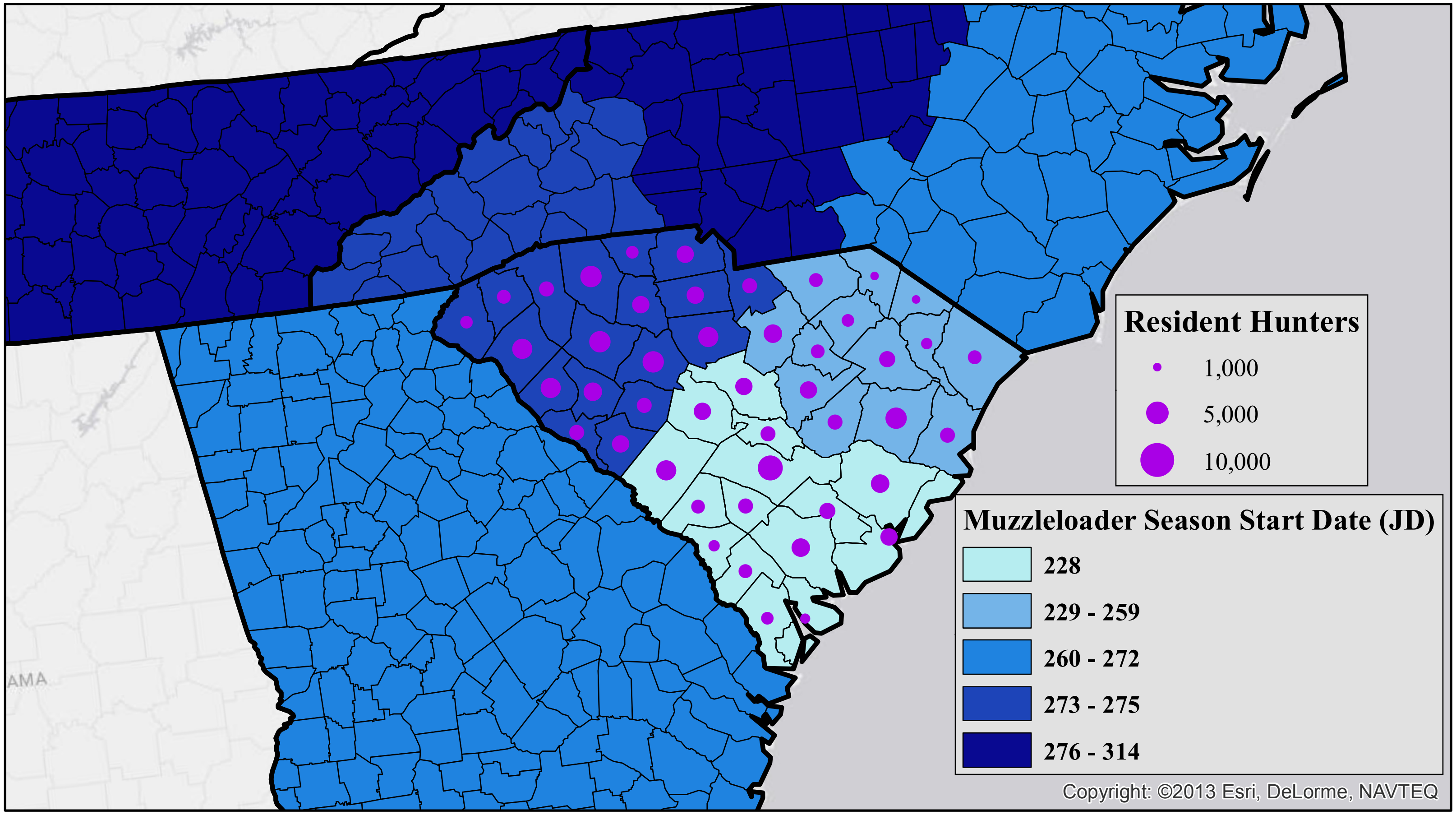

Figure 6.11: Map showing the muzzleloader season start dates as the Julian Date (JD) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of South Carolina resident hunters.

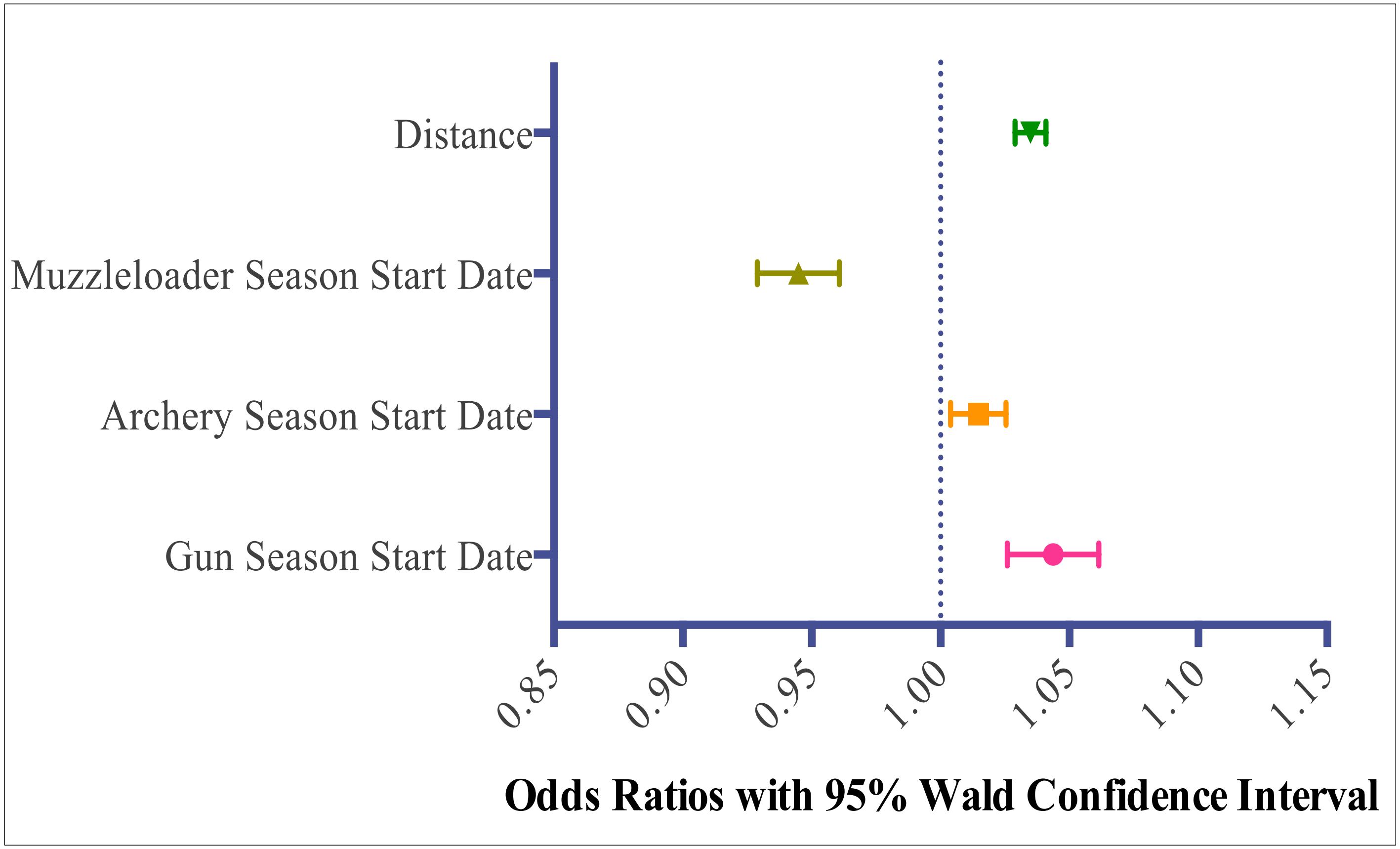

Figure 6.12: Odds ratio and corresponding confidence intervals for the independent variables from the resident hunter by season start date (Julian Date) model (the dotted line is at OR=1)

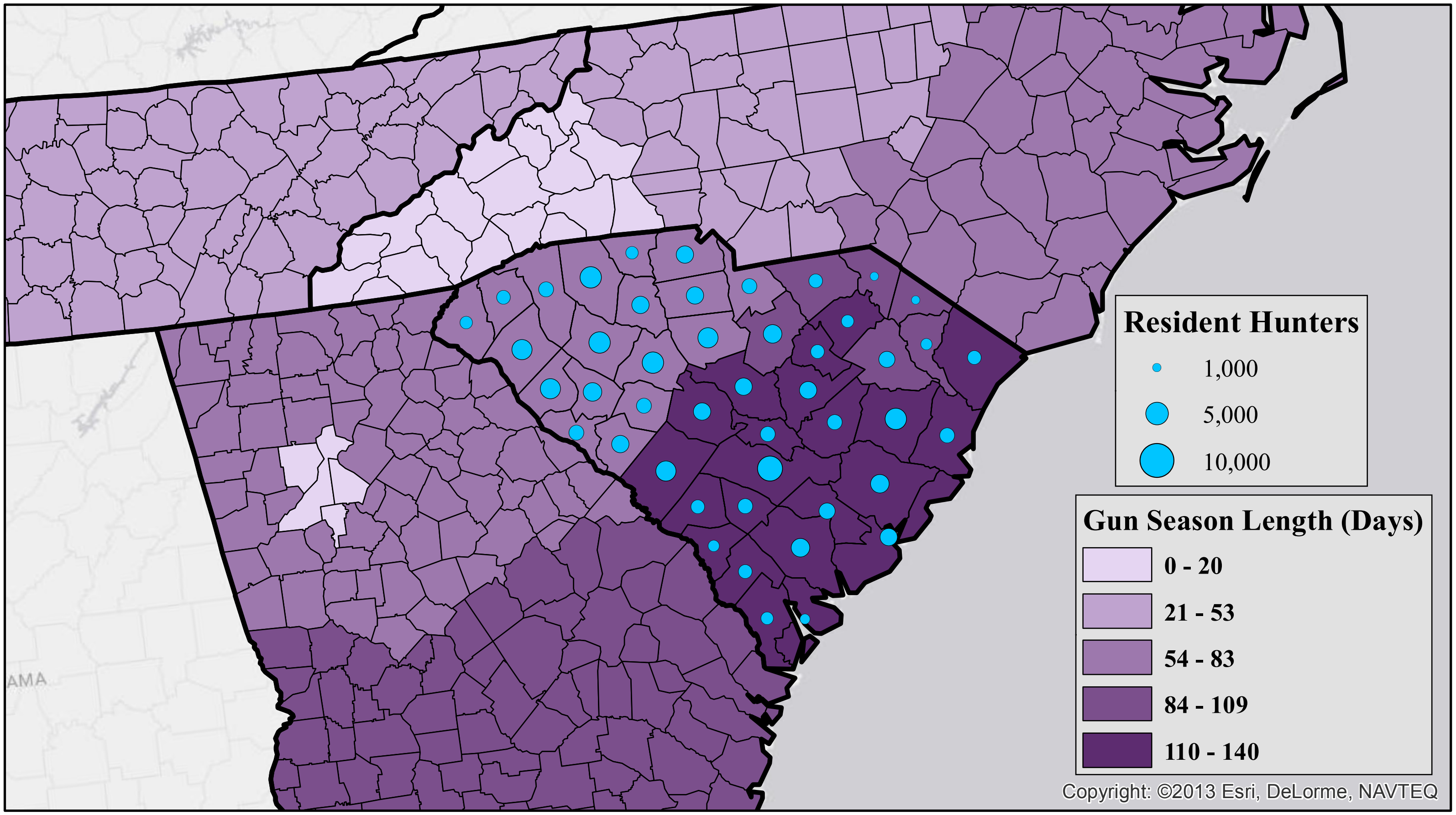

Figure 6.13: Map showing the gun season lengths (days) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of South Carolina resident hunters

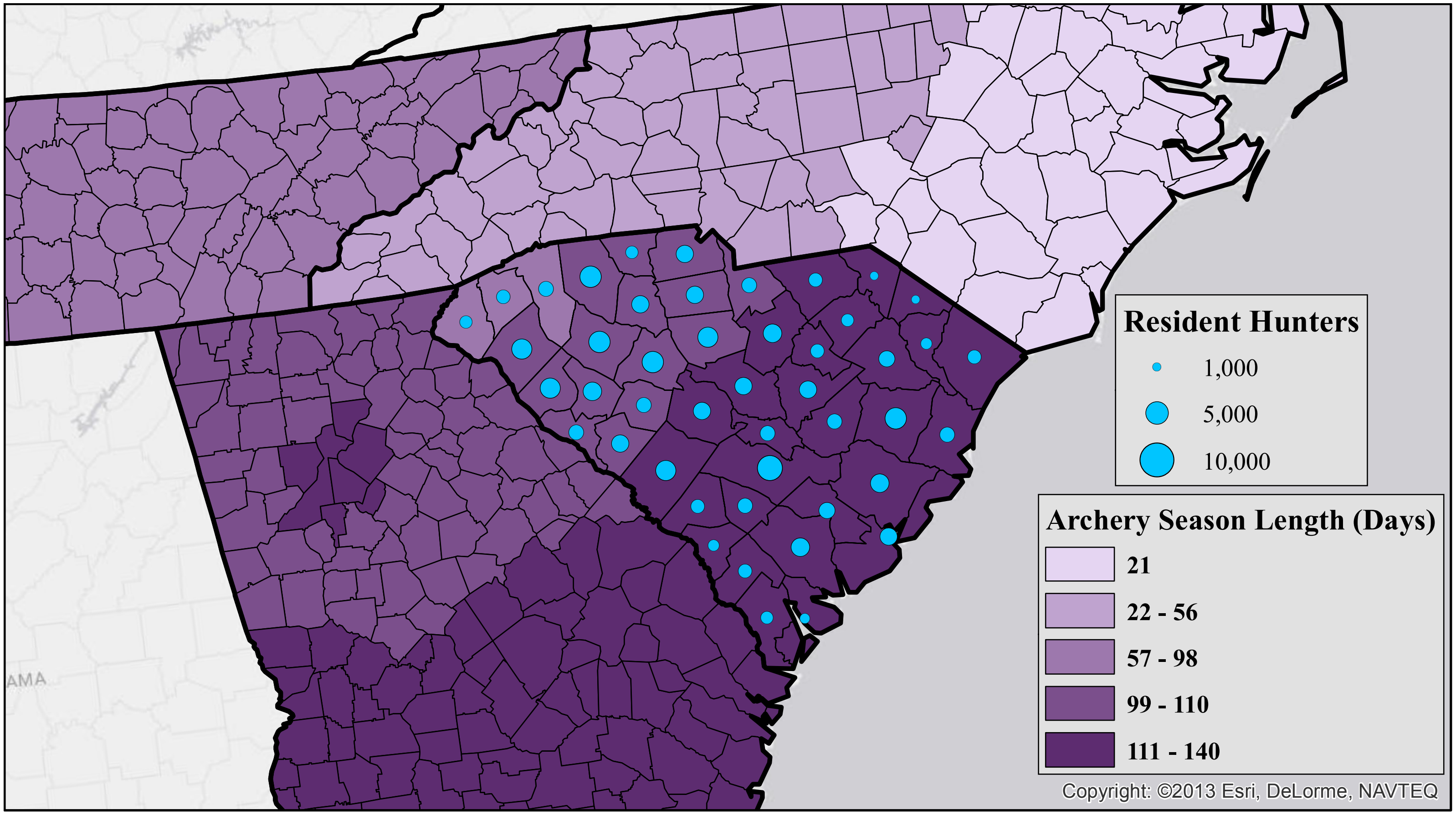

Figure 6.14: Map showing the archery season lengths (days) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of South Carolina resident hunters

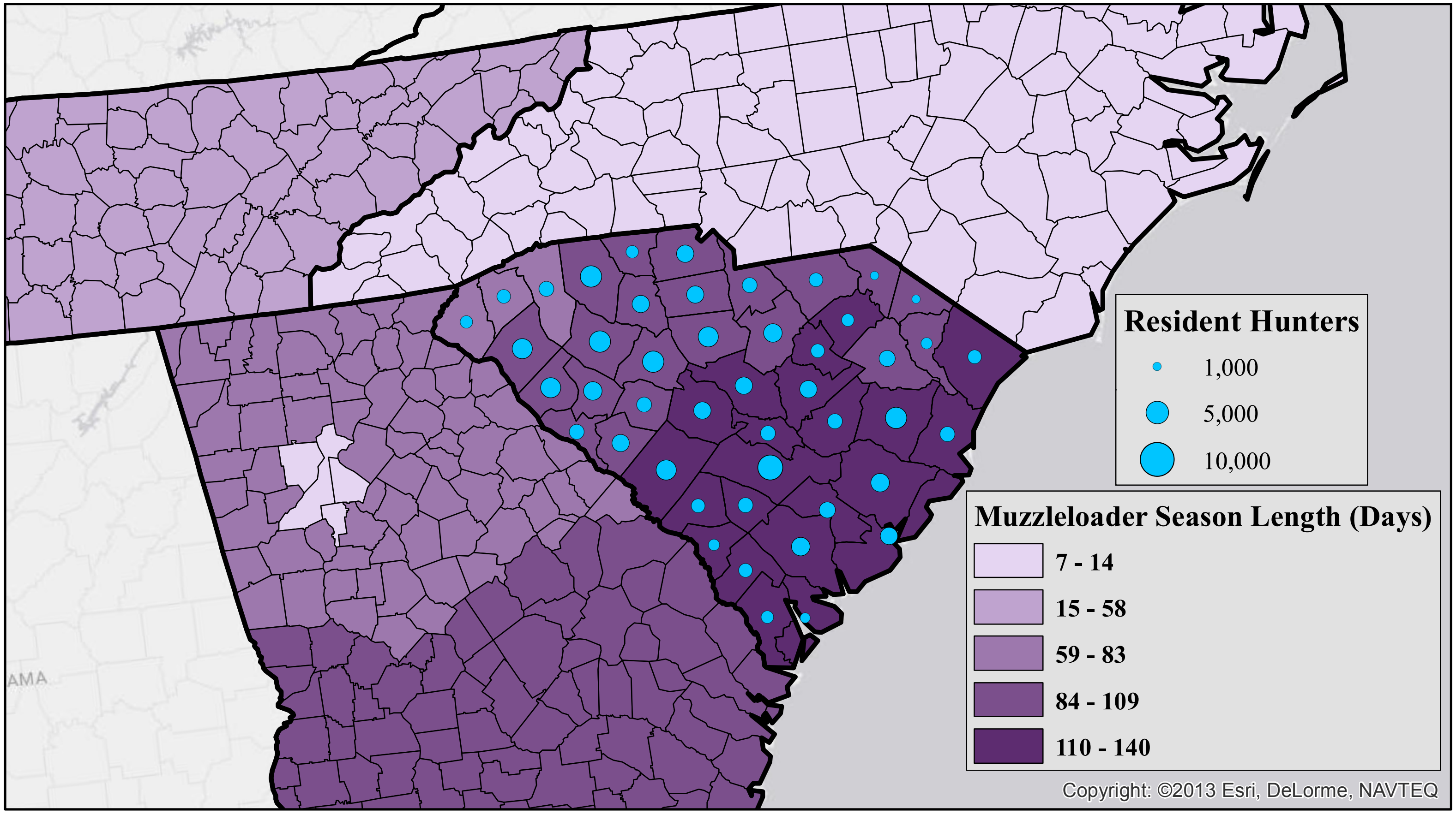

Figure 6.15: Map showing the muzzleloader season lengths (days) for Georgia, North Carolina, South Carolina, and Tennessee counties with an overlay of the number of South Carolina resident hunters

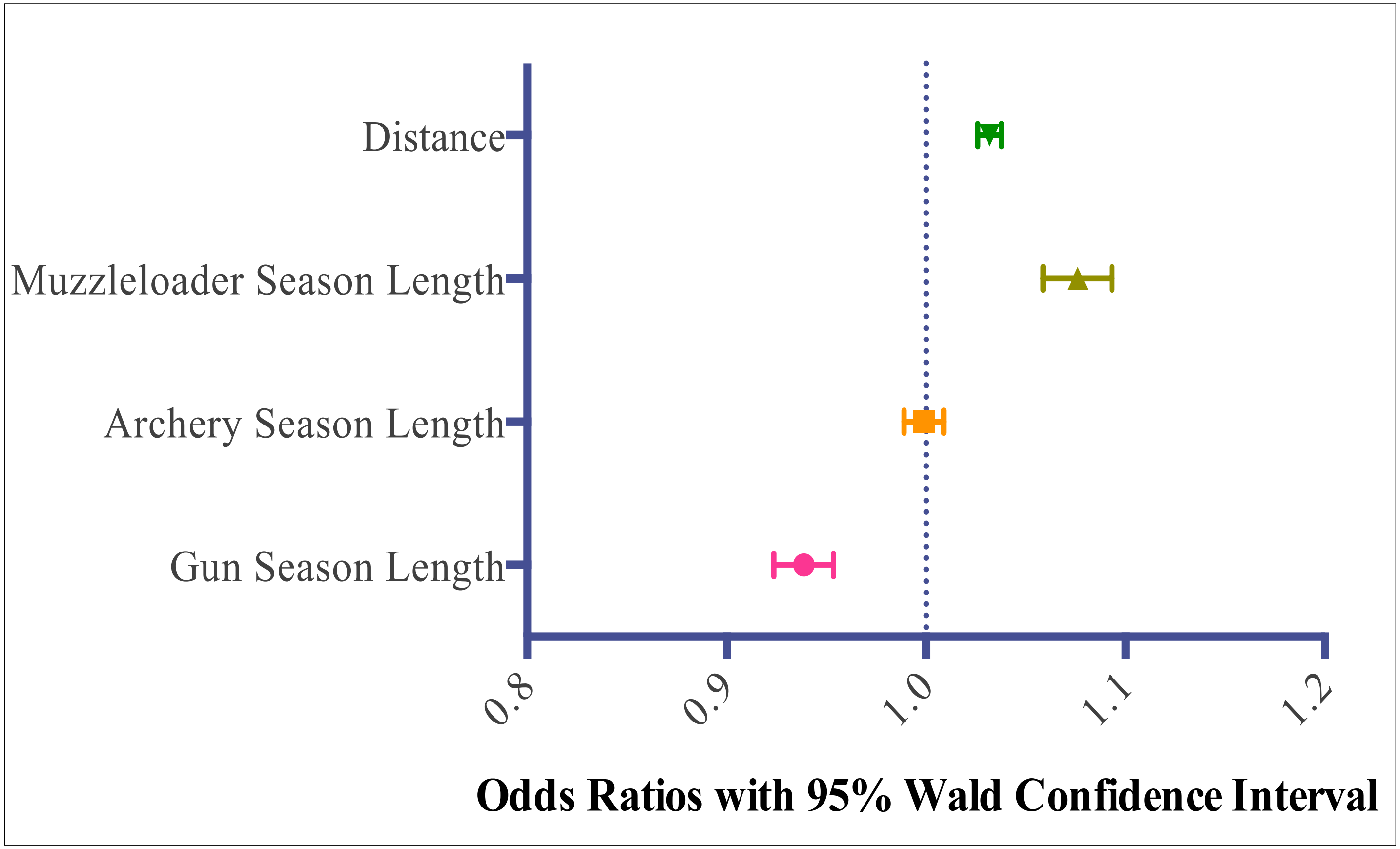

Figure 6.16: Odds ratio and corresponding confidence intervals for the independent variables from the resident hunter by season lengths (days) model (the dotted line is at OR=1)

CHAPTER SEVEN

MODELING TOTAL WHITE-TAILED DEER HARVEST

7.1 PARSIMONIOUS MODEL

The parsimonious model for total white-tailed deer harvest suggests that changes to any of the eight predictors in the final model will result in decreases or increases in the predicted total deer harvest depending on the direction of influence of the independent variable (Table 7.1, Figure 7.1). To see an increase in total white-tailed deer harvest, the parsimonious model suggests decreasing the gun season length, as seen by the significant negative relationship (19.12% decrease in total harvest for every 1 day increase in gun season length; OR: 0.8088; 95% CL: 0.7718, 0.8475; Table 7.1). When considering archery season length, there is an expected 4.46% decrease in total harvest for every 1-day increase in archery season length (OR: 0.9554; 95% CL: 0.9409, 0.9701). Muzzleloader season length shows a significant positive relationship with total white-tailed deer harvest (Table 7.1), and its influence on total harvest is larger than the other season lengths (25.09% increase in total harvest for every 1 day increase in muzzleloader season length; OR: 1.2509; 95% CL: 1.1922, 1.3124). Muzzleloader Season Start Date and Gun Season Start Date were not included in the final model because these two variables were not significant using the parsimonious method.

The relationship between archery season start date and total harvest is negative (4.77% decrease in total harvest for every 1 day increase in archery season start date; OR: 0.9523; 95% CL: 0.938, 0.9669; Table 7.1). The model shows an expected 1.95%

increase in total harvest for every 1% increase in individual effort (OR: 1.0195; 95% CL: 1.0024, 1.0369). The influence of either sex gun season length on total harvest in the parsimonious model is much larger than the influence of either sex archery season length. The relationship between either sex gun season length and total harvest is positive (16.38% increase in total harvest for every 1 day increase in either sex gun season length; OR: 1.1638; 95% CL: 1.132, 1.1956; Table 7.1), but the relationship between either sex archery season length and total harvest is negative (1.42% decrease in total harvest for every 1 day increase in either sex archery season length; OR: 0.9858; 95% CL: 0.9804, 0.9912; Table 7.1). The model shows an expected 0.26% increase in total harvest for every 1 square mile increase in deer habitat (in square miles) of the county (OR: 1.0026; 95% CL: 1.0023, 1.0029).

7.2 NONPARSIMONIOUS MODEL

Using only the season lengths and start dates to model white-tailed deer total harvest allowed me to see the relationship of each with total harvest given when other season lengths and start dates are held constant (Table 7.2, Figure 7.2). Archery season length (OR: 0.9987; 95%CL: 0.9915, 1.006) and archery season start date (OR: 1.0045; 95%CL: 0.9981,1.0109) are not significant in this model (Table 7.2). There is an expected 3.22% increase in total harvest for every 1-day increase in gun season length (OR: 1.0322; 95% CL: 1.0242, 1.0403). This model shows an expected 1.83% increase in total harvest for every 1-day increase in gun season start date (OR: 1.0183; CL: 1.0082, 1.0286). Both muzzleloader season length (0.96% increase in total harvest for every 1 day increase in muzzleloader season length; OR: 1.0096, 95% CL: 1.0004, 1.0189) and muzzleloader season start date (0.92% increase in total harvest for every 1 day increase in muzzleloader season start date; OR: 1.0092; 95% CL: 1.004, 1.0145) have significant positive relationships with total harvest (Table 7.2).

7.3 CHAPTER SEVEN CONCLUSIONS

In both the parsimonious and nonparsimonious model, the gun season length and muzzleloader season length are significant predictors for the total white-tailed deer harvest. Therefore, when deer managers are deciding on harvest regulations, special attention should be paid to the length of these seasons and how total harvest will respond to changes implemented by deer managers. Furthermore, deer managers should make sure any changes in total harvest align with their management goals for the state. Both the total harvest models suggest an expected increase in total harvest when the muzzleloader season length is increased. However, the gun season length suggestions are opposite for the models. Decreasing the gun season length in the parsimonious model, but increasing it in the nonparsimonious model shows an expected increase in total harvest.

The parsimonious model suggests that starting the archery season earlier or decreasing the archery season length can increase total harvest. Total harvest could also be increased by increasing individual hunter effort, having longer either sex gun season lengths, a slightly shorter either sex archery season lengths, or a very small increase in the amount of deer habitat in the county. The nonparsimonious model suggests that gun season start date and muzzleloader season start date are significant, and an increase in either will result in an expected increase in total harvest.

An indicator of the relative influence of each variable on total white-tailed deer harvest is the percent change in total harvest that the variable is predicted influence (Figures 7.1 & 7.2). In the parsimonious total harvest model, the three variables with the largest influence are muzzleloader season length (25.09%), gun season length (19.12%), and either sex gun season length (16.38%). For the nonparsimonious model, the three variables with the greatest influence are gun season length (3.22%), gun season start date (1.83%), and muzzleloader season length (0.96%). Managers should pay attention to the variables with larger influences, because of the possibility that even minor changes to these variables could have a large impact on white-tailed deer total harvest.

7.4 CHAPTER TABLES

Table 7.1: Chi^2, p-values, odds ratio, and confidence limits for variables in the parsimonious total harvest model

Source	X^2	P-value	Odds Ratio	95% Confidence Limits	
Gun Season Length	79.12	<.0001	0.8088	0.7718	0.8475
Archery Season Length	34.36	<.0001	0.9554	0.9409	0.9701
Muzzleloader Season Length	83.44	<.0001	1.2509	1.1922	1.3124
Archery Season Start Date	39.89	<.0001	0.9523	0.9380	0.9669
Individual Effort	5.00	0.0254	1.0195	1.0024	1.0369
Either Sex Gun Season Length	114.91	<.0001	1.1638	1.1320	1.1965
Either Sex Archery Season Length	26.37	<.0001	0.9858	0.9804	0.9912
Habitat Area (Sq. Mi.)	285.08	<.0001	1.0026	1.0023	1.0029

Table 7.2: Chi², p-values, odds ratio and confidence limits for the variables in the nonparsimonious total harvest model

Source	X^2	P-value	Odds Ratio	95% Confidence Limits	
Gun Season Length	64.25	<0.0001	1.0322	1.0242	1.0403
Gun Season Start Date	12.71	0.0004	1.0183	1.0082	1.0286
Archery Season Length	0.12	0.7283	0.9987	0.9915	1.0060
Archery Season Start Date	1.92	0.1657	1.0045	0.9981	1.0109
Muzzleloader Season Length	4.21	0.0402	1.0096	1.0004	1.0189
Muzzleloader Season Start Date	12.08	0.0005	1.0092	1.0040	1.0145

7.5 CHAPTER FIGURES

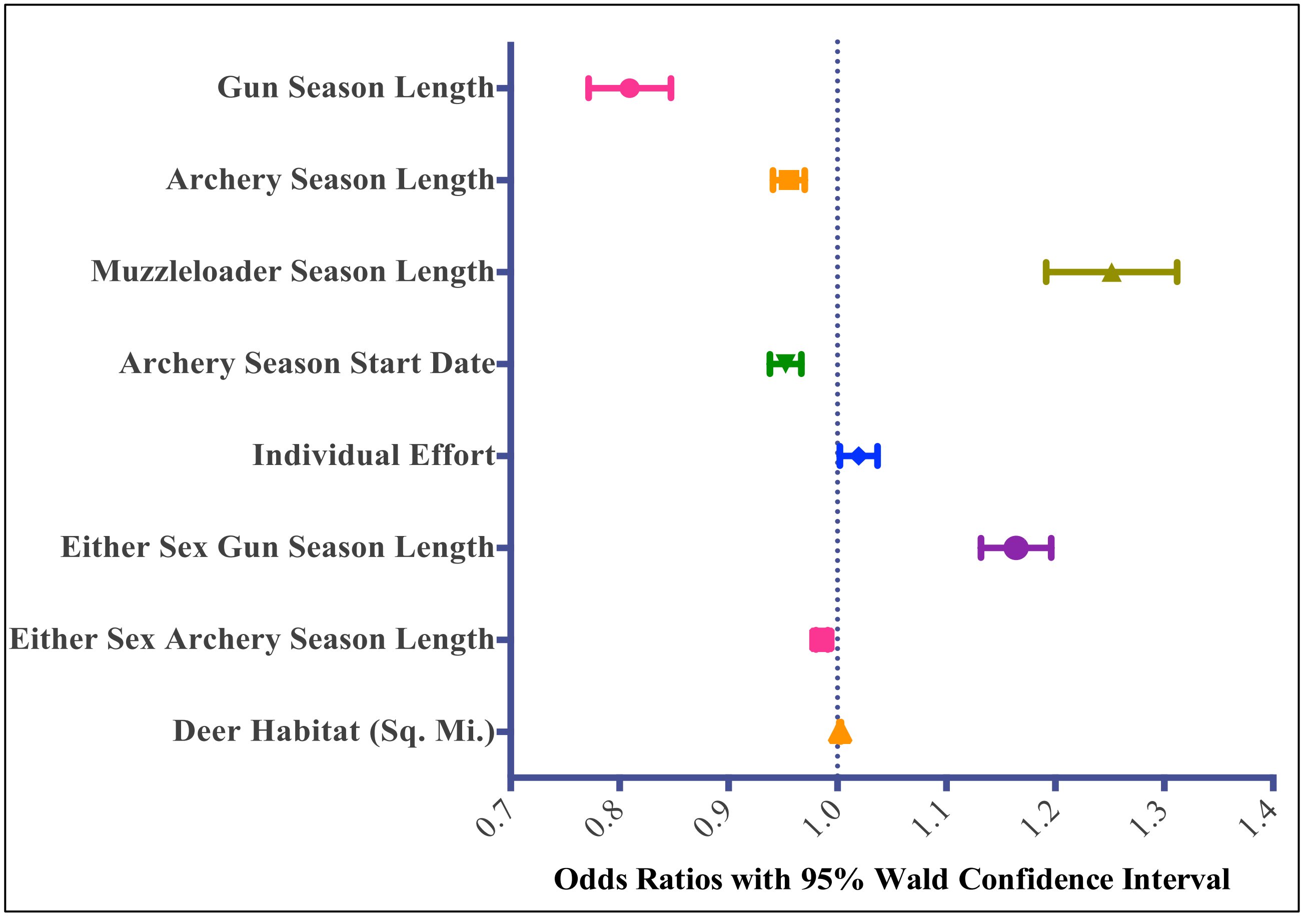

Figure 7.1: Odds ratio and corresponding confidence intervals for the independent variables from the parsimonious total harvest model (the dotted line is at OR=1)

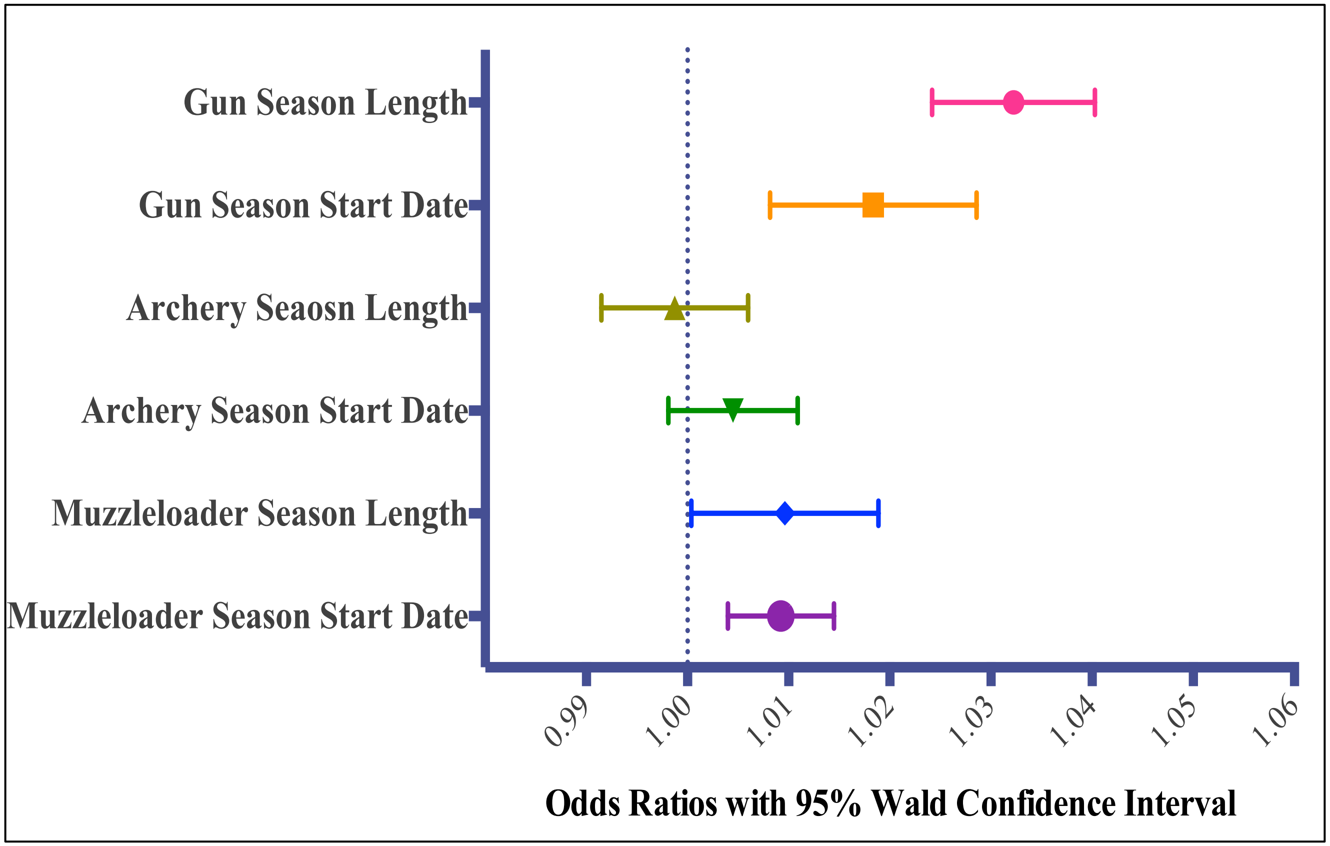

Figure 7.2: Odds ratio and corresponding confidence intervals for the independent variables from the nonparsimonious total harvest model (the dotted line is at OR=1)

CHAPTER EIGHT

MODELING WHITE-TAILED DEER DOE HARVEST

8.1 PARSIMONIOUS MODEL

The parsimonious model for white-tailed deer doe harvest suggests that changes to any of the six independent variables in the final model will result in decreases or increases in the predicted doe harvest depending on the direction of influence of the independent variable (Table 8.1, Figure 8.1). There is a significant positive relationship between gun season length and doe harvest (4.95% increase in doe harvest for every 1 day increase in gun season length; odds ratio: 1.0495; 95% confidence limits [CL]: 1.0439, 1.0552; Table 8.1). There is an expected 2.31% increase in doe harvest for every 1-day increase in archery season length (OR: 1.0231; 95% CL: 1.0181, 1.0280), conversely there is an expected 3.5% decrease in doe harvest for every 1-day increase in muzzleloader season length (OR: 0.9650; 95% CL: 0.9579, 0.9722). The significant relationship between either sex gun season length and doe harvest is negative (0.57% decrease in doe harvest for every 1 day increase in either sex gun season length; OR: 0.9943; 95% CL: 0.9919, 0.9966). On the other hand, either sex archery season length and doe harvest have a positive relationship (1.8% increase in doe harvest for every 1 day increase in either sex archery season length; OR: 1.0180; 95% CL: 1.0162, 1.0199). There is an expected 0.38% increase in doe harvest for every 1 square mile increase in deer habitat (in square miles) for the county (OR: 1.0038; 95%CL: 1.0035, 1.0041). Muzzleloader Season Start Date, Gun Season Start Date, Individual Effort, and Archery

Season Start Date were not included in the final model because these variables were not significant using the parsimonious method

8.2 NONPARSIMONIOUS MODEL

Using only the season lengths and start dates to model white-tailed deer doe harvest allowed me to see the relationship of each with doe harvest when all other season lengths and start dates are held constant (Table 8.2, Figure 8.2). Archery season length (OR: 1.0005; 95%CL: 0.9918, 1.0092) and archery season start date (OR: 1.0003; 95%CL: 0.9928, 1.0078) are not significant in this model, because their 95% confidence limits span 1 and their p-values are much greater than 0.05 (Table 8.2). All the significant variables for this model have a positive relationship with doe harvest. There is an expected 4.43% increase in doe harvest for every 1-day increase in gun season length (OR: 1.0443; 95% CL: 1.0341, 1.0545). Gun season start date (3.36% increase in doe harvest for every 1 day increase in gun season start date; OR: 1.0336; 95% CL: 1.0206, 1.0467), muzzleloader season length (1.09% increase in doe harvest for every 1 day increase in muzzleloader season length; OR: 1.0109; 95%CL: 1.0000, 1.0219), and muzzleloader season start date (0.88% increase in doe harvest for every 1 day increase in muzzleloader season start date; OR: 1.0088; 95%CL: 1.0023, 1.0153) are significant in the nonparsimonious doe harvest model.

8.3 CHAPTER EIGHT CONCLUSIONS

The two models for doe harvest tell very different stories, but the one common suggestion is that an increase in gun season length is expected to result in an increased doe harvest. One difference is that in the parsimonious model all the season lengths are significant, but in the nonparsimonious model the archery season length is no longer significant. Second, the direction of the magnitude for muzzleloader season length is opposite between the models. Since the models tell different stories about doe harvest, I will be giving the conclusions for objective in separate paragraphs.

The parsimonious model suggests that extending the duration of the gun or archery season length can result in an increase in doe harvest. Decreasing the muzzleloader season length is another suggestion made by the model to increase doe harvest. The doe harvest parsimonious model suggests that increases in deer habitat per county could result in an increased doe harvest. The parsimonious doe harvest model also recommends increasing doe harvest by decreasing either sex gun season length or increasing either sex archery season length. The nonparsimonious doe harvest model suggests increasing doe harvest by increasing any of the significant season length variables, gun season length and muzzleloader season length. Another suggestion to increase doe harvest is to have the gun season start date or the muzzleloader season start date occur later in the year. Archery season start date and archery season length are not significant in this model. An indicator of the relative influence of the variable on total white-tailed deer doe harvest is the percent change the variable causes doe harvest (Figures 8.1 & 8.2). In the parsimonious doe harvest model, the three variables with the greatest influence are gun season length (4.95%), muzzleloader season length (3.5%), and archery season length (2.31%). For the nonparsimonious model, the three variables with the largest influence are gun season length (4.43%), gun season start date (3.36%), and muzzleloader season length (1.09%). Managers should pay attention to the variables with the greater influences, because of the possibility that even minor changes to these variables could have a large impact on white-tailed deer doe harvest.

8.4 CHAPTER TABLES

Table 8.1: Chi², p-values, odds ratio, and confidence limits for variables in the parsimonious doe harvest model

Source	X^2	P-value	Odds Ratio	95% Confidence Limits	
Gun Season Length	308.14	<.0001	1.0495	1.0439	1.0552
Archery Season Length	85.53	<.0001	1.0231	1.0181	1.0280
Muzzleloader Season Length	89.18	<.0001	0.9650	0.9579	0.9722
Either Sex Gun Season Length	22.46	<.0001	0.9943	0.9919	0.9966
Either Sex Archery Season Length	371.12	<.0001	1.0180	1.0162	1.0199
Deer Habitat (Sq. Mi.)	756.83	<.0001	1.0038	1.0035	1.0041

Table 8.2: Chi^2, p-values, odds ratio, and confidence limits for variables in the nonparsimonious doe harvest model

Source	X^2	P-value	Odds Ratio	95% Confidence Limits	
Gun Season Length	75.96	<0.0001	1.0443	1.0341	1.0545
Gun Season Start Date	26.29	<0.0001	1.0336	1.0206	1.0467
Archery Season Length	0.01	0.9162	1.0005	0.9918	1.0092
Archery Season Start Date	0.01	0.9354	1.0003	0.9928	1.0078
Muzzleloader Season Length	3.81	0.0509	1.0109	1.0000	1.0219
Muzzleloader Season Start Date	7.12	0.0076	1.0088	1.0023	1.0153

8.5 CHAPTER FIGURES

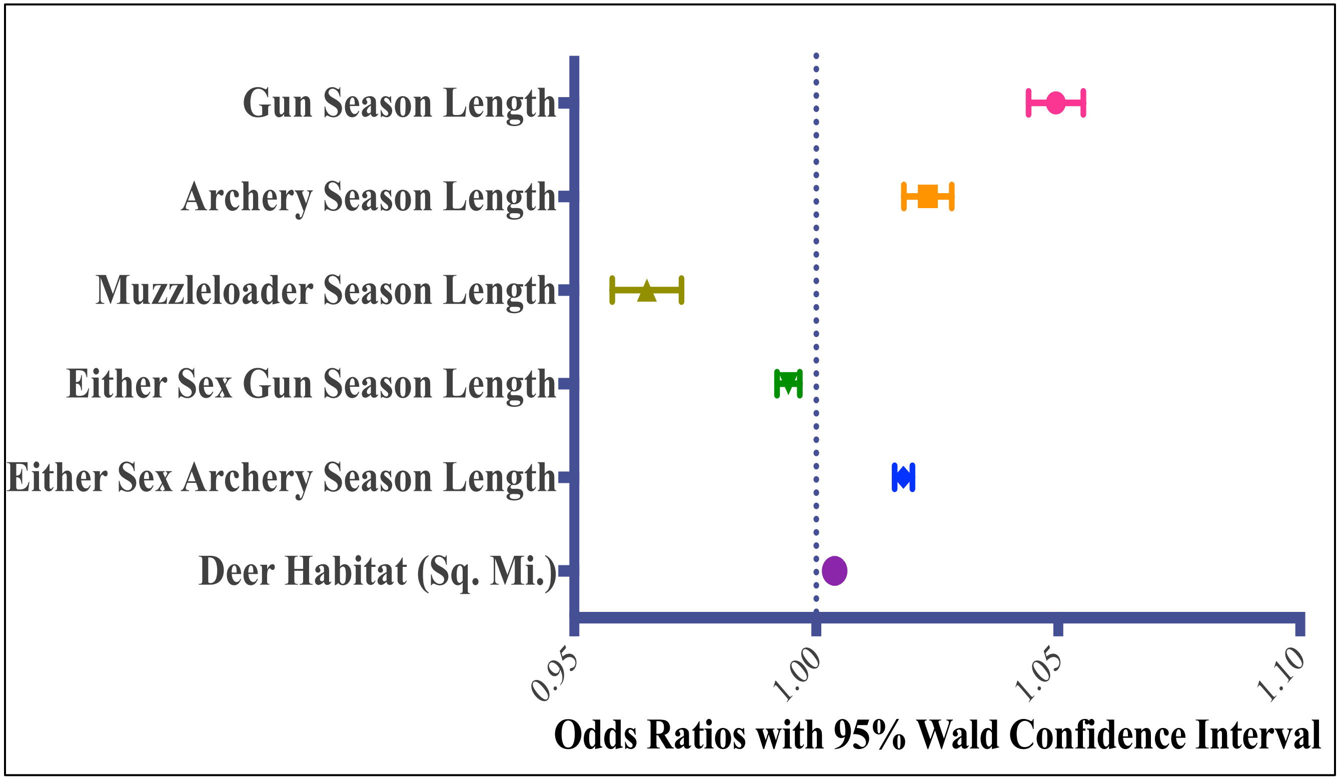

Figure 7.1: Odds ratio and corresponding confidence intervals for the independent variables from the parsimonious doe harvest model (the dotted line is at OR=1)

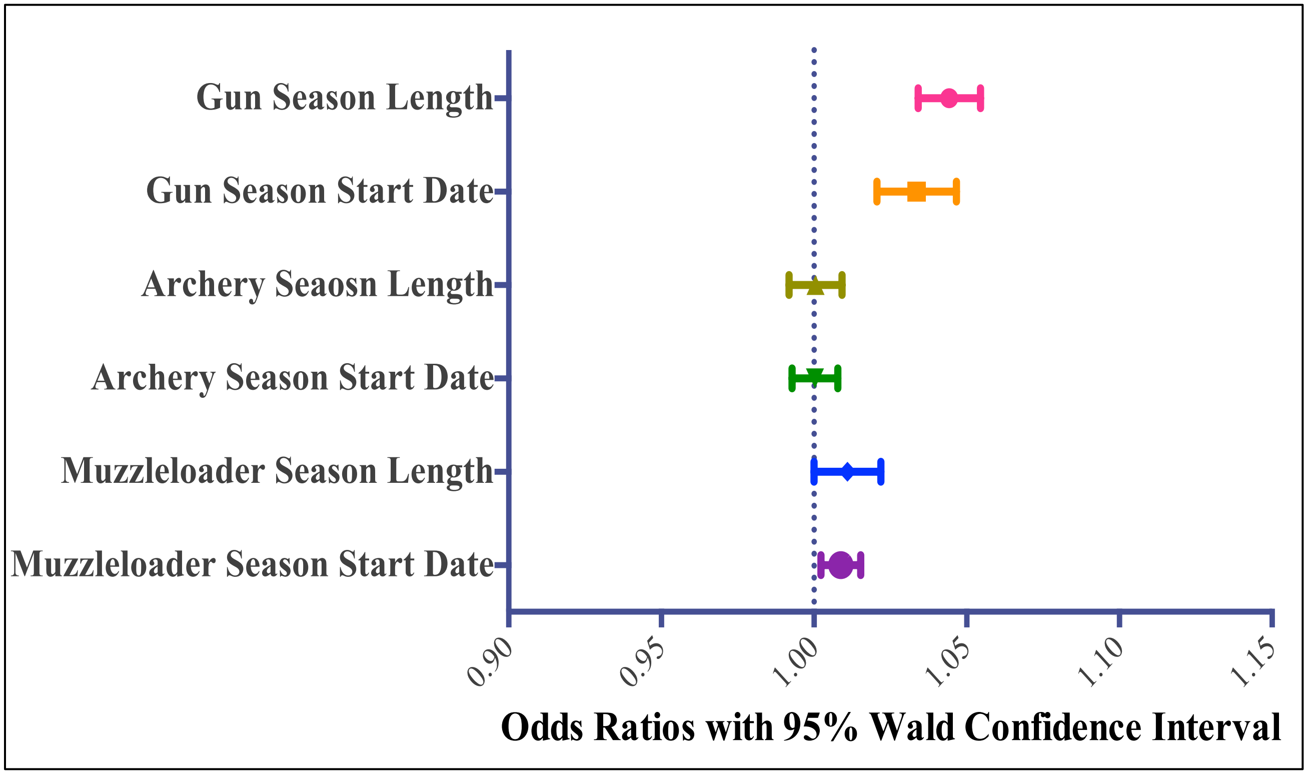

Figure 7.2: Odds ratio and corresponding confidence intervals for the independent variables from the nonparsimonious doe harvest model (the dotted line is at OR=1)

CHAPTER NINE

IMPLICATIONS OF RESEARCH

9.1 SUMMARY OF POSSIBLE MANAGEMENT IMPLICATIONS

Through the completion of the objectives of this research mentioned in Chapter One, some of the results of the analyses have implications for white-tailed deer management. The broad suggestions made in this section are meant to point out significant findings from my research to the state deer managers to implement or keep in mind when setting hunting and/or harvest regulations. The adaptability of the suggestions in this chapter will depend on the states harvest goals. Since damage caused from overabundant deer populations is so extensive, I focused most of my suggestions toward an ultimate goal of increasing doe harvest.

To answer my first research question that similar states have equivalent management strategies for their white-tailed deer herds, I found that just because states are extremely similar in many ways does not necessarily mean they will have similar management strategies or harvest outcomes. South Carolina consistently showed a larger harvest for the total, buck, and doe harvest categories. The larger harvests of South Carolina could be a result of the longer seasons and/or how much earlier South Carolina starts all of its hunting seasons. From these results we can conclude that state deer managers should keep in mind that the management practices of another state, no matter how similar the states seem might be different. Furthermore, managers should be cautious if they attempt to implement another state's white-tailed deer management policy because a management strategy that works well in one state will not necessarily work the same in another state.

The results from this research gave strong evidence that although the number of hunters is important, hunter effort is more correlated with total harvest and doe harvest, consequently answering my second research question. Although hunter effort (in days) is a fairly accurate measure of total hunter effort, it is not as precise as using the number of hours spent hunting. Until a more precise measure for hunter effort is used, hunter effort (in days) should be viewed as a minimum estimate for effort. Furthermore, since hunter effort is more correlated with total harvest and doe harvest than the number of hunters, it would be a more efficient allocation of the state deer managers' time to work on programs that entice their current citizen hunters to spend more time in the field hunting, if the state's goal is to increase harvest in the area.

Based on results of my analysis from the data I had available, it appears that managers do not need to strictly regulate the archery season length or archery season start date when attempting to increase total effort. I found both variables to be insignificant predictors of total hunter effort. However I am not advocating that managers should completely ignore the regulatory variables, but rather allocate resources to the variables that are predicted to have the greatest affect. These total effort models from Chapter 5 predicted an increase in total hunter effort by having an earlier gun season, having a later muzzleloader season, or increasing the duration of the gun season. Only one of the three suggestions can be implemented at one time, because the model calculated the influence of each variable when all the other variables are held constant. Therefore, using more than one model suggestion at a time could have an outcome vastly different than the results were originally intended.

Alternatively, in states where the number of hunters is declining steadily (i.e. Tennessee), deer managers should embrace programs that attract a large and diverse group of people. A report by Southwick Associates (2010) revealed that the majority of hunters in the Southeast (93%) were male and averaged roughly 42 years of age. Consequently, recent promotions by professionals with wildlife and hunting attachments to get women and younger people involved in hunting have been successful. Lately, increased recruitment of female and youth hunters has helped to slow down the decline in the number of white-tailed deer hunters (Hewitt, 2011).

My research results verified that hunting season lengths and start dates do have an influence on the number of resident and nonresident hunters in the county, which answered my third research question. Unfortunately South Carolina was the only state with resident and nonresident hunter data, so I cannot extrapolate my results to any other states. The influence that each of the hunting season lengths and hunting season start dates has on estimated number of nonresident hunters is important, especially if the hunting behaviors of nonresident hunters differ significantly from the behavior of resident hunters (i.e. if nonresident hunters harvest a significantly greater number of bucks than resident hunters). The Southwick Associate (2010) report found that the southeastern and the western regions of the United States drew the greatest percentage of nonresident hunters (Figure 4: Southwick Associates, 2010), which only further illustrates the practicality of understanding the potential differences in hunting behaviors.

An important consideration for deer managers when they are developing white-tailed deer regulations and harvest goals would be knowing how changes to these regulatory variables are predicted to influence resident and nonresident hunter behavior. This research only looked at the influence of hunting season start dates and season length, and based on my results I concluded that the predicted numbers of resident and nonresident hunters are comparably affected by changes in those two hunting season parameters. The only major difference that I found in my analysis was in where the two groups hunted. Residents were more dispersed around the state and, as the distance of the county from the border increases, so does the predicted number of resident hunters. The opposite is true for nonresident hunters, and as the county's distance from the border increases, the predicted number of nonresident hunters decreases. This difference in hunting areas can lead to a greater proportion of nonresident hunters in the border counties, which in turn could hinder management goals if the nonresidents are only visiting to "trophy" hunt and not to help manage the population.

My results from the total harvest and doe harvest regressions showed that the nonparsimonious models for total harvest and doe harvest were similar, but that the parsimonious models were found to be quite different. My fourth research question was answered by descriptions of the models found using the parsimonious and nonparsimonious methods (Chapters 7 & 8). The models described in these chapters should be taken with a grain of salt, because there are numerous variables that influence the two types of harvest. These models certainly do not account for all of the many variables that might influence harvest (i.e. chemical concentration of the soil, how accessible the habitat areas are to hunters, license costs, ammunition costs, etc.).

Nonetheless I did choose to model the regulatory variables that could be relatively easily manipulated by deer managers (i.e. season lengths, either sex season lengths, etc.). Furthermore, by including the amount of predicted deer habitat in my models, I was able to interpret the other variables in my models holding the amount of predicted deer habitat fixed. This allowed me to account for the large diversity of habitat types across the different states.

The magnitudes for season start dates and season lengths of the gun and muzzleloader seasons were found to be significant for both of the nonparsimonious models, plus the direction of magnitude remained the same. When making annual hunting regulations deer managers should use extra caution when manipulating the muzzleloader season length and the gun season length. These two variables were not only significant for both of the nonparsimonious models, but were also significant for the two parsimonious models of total harvest and doe harvest.

When using the parsimonious method to model total harvest and doe harvest, most of the variables that were significant for both models had magnitudes with conflicting signs. Notwithstanding, deer habitat area (in square miles) was significant and holds a positive magnitude in both models. The magnitude for deer habitat (in square miles) is small and most likely minor changes in this variable will probably not result in a noticeable difference in the total or doe harvests. However, deer managers should be wary of the accumulation of these slight changes when they negatively impact the amount of deer habitat (i.e. agriculture, deforestation, urbanization, etc.), because over time this accumulation could cause a decrease in total or doe harvests.

9.2 FUTURE DIRECTIONS

In this section, I want to take time to discuss several thoughts I believe should be considered to improve white-tailed deer harvest data management in the future. I believe that the collection and interpretation of white-tailed deer harvest data could be improved through data uniformity across the states, changing how some variables are defined, and even performing and analyzing results of other studies to better understand harvest data consequences. First, it would be great to conduct a study focusing on all aspects of the hunting behaviors of resident and nonresident hunters to determine if the two groups show significant differences in their hunting behavior. Knowing how different variables are predicted to influence hunter behavior is a very important consideration for managers when they are developing white-tailed deer harvest goals. Unfortunately, my resident and nonresident data is only for South Carolina counties, so it is difficult to extrapolate these findings across the Southeast. Likewise, the nonresident data is defined as the number of out-of-state hunters, but it would be interesting to see the results if deer managers distinguished resident and nonresident hunters by the county in which they reside instead of the state. Since the counties within a single state can have different hunting season lengths and season start dates, I believe hunters within the state would travel to other counties for an earlier and/or longer hunting opportunity. I believe that having the resident/nonresident information for the counties of many different states will yield different results, because this data collection is going to increase the sample size of the model and the information would be coming from more than just South Carolina.

Additionally, the number of nonresident hunters for each county does not take into account the timing of the nonresident hunters' presence in the county. For example, there could be large numbers of nonresident hunters at the beginning of the hunting season and their numbers diminish over the course of the season, vise versa. Information like this would be a challenge to collect, but in obtaining this, deer managers would be able to display a more understandable picture concerning the happenings in a state, county, or wildlife management unit during the white-tailed deer hunting seasons.

Hopefully at this point a few people are convinced of the importance of analyzing white-tailed deer harvest data at larger scales than just the area being managed in order to show trends in the Southeastern deer herds. Having the detailed data mentioned previously for the majority of the states would enable white-tailed deer managers in every state to quickly interpret the data and make conclusions about what is occurring in other states, benefitting the deer manager in many ways. This understanding would allow managers to answer citizen hunter's questions more efficiently and better see the emergence of trends through time in other states that might impact a state's deer herd or hunters (i.e. a trend of earlier starting hunting seasons that could influence the number of nonresident hunters that pay money to hunt in your state).

Lastly, I believe that state deer managers should attempt to collect consistent data across states in the region to facilitate better interstate communications regarding state deer herds and management problems, practices, and results. I realize that this idea will take a lot of time and coordination and would have to include every state's deer manager. Nevertheless I believe that deer management agencies could rise to the challenge and create an online dataset for white-tailed deer harvest and other important variables that all deer managers could use to more accurately analyze trends across the species' extensive geographic range.

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APPENDIX A: DEFINITIONS OF VARIABLES USED IN RESEARCH

Table A.1: Definitions and units of all my research variables

Variable	Definition	Units
Harvest	the term used to describe the killing/removal of white-tailed deer from the environment	
Total Harvest	the total number of white-tailed deer killed during the season	
Buck Harvest	the total number of Buck (male) white-tailed deer killed	
Doe Harvest	the total number of Doe (female) white-tailed deer killed	
Gun Harvest	the total number of buck and doe white-tailed deer killed using a gun, typically a rifle. The weapons allowed vary from state to state	
Archery Harvest	the total number of buck and doe white-tailed deer killed using a bow and arrow, traditional or compound allowed. Crossbows are allowed in some states during the archery season	
Muzzleloader Harvest	the total number of buck and doe white-tailed deer killed using a muzzleloader, some states refer to guns in this category as “Black Powder”	
Harvest Density= Harvest Type/ Area of County or State (in Square Miles);		Deer/ Sq. Mi.
Hunting Season	the season is described my the type of weapon allowed (Gun, Archery, Muzzleloader)	
Hunting Season Start Date	the first day (opening day) of the season;	Julian Dates (JD)
Hunting Season Length	a count of the number of days the season occurs	Days
Total (Hunter) Effort	the cumulative number of days the hunters spent in the field	Days
Hunter Effort Density= Total (Hunter) Effort/ Area of County or State		Days/ Sq. MI

Table A.1 Continued

Variable	Definition	Units
Individual Effort= Total (Hunter) Effort/ Total Number of Hunters		Days/ Hunter
Total Number of Hunters	the count data for the number of hunters in that area	
Nonresident Hunters	Hunters that do not live in the state where they were hunting; out-of-state hunters	
Resident Hunters	Hunters that hunt in the same state they live in	
Hunter Number Density= Total Number of Hunters/ Area of County or State		Hunters/ Sq. MI
Percent Doe= Doe Harvest/ Total Harvest * 100		
Habitat Area	The amount of predicted deer habitat I calculated using the information from the Southeast GAP Analysis Project	Sq. MI
Percent Deer Habitat= Habitat Area/ Area of County * 100		
Distance	How far the geometric mean of the county is from the closest state boarder	
Harvest tags	Once a deer has been harvested, the hunter must attach a tag to it	
Doe Tags	If a hunter harvests a doe and it is not an Either Sex Day, s/he must have a doe tag and attach before taking it away from the area	
Either Sex Seasons	During these seasons, hunters may harvest buck or doe deer without a [doe] tag. The season is a few days throughout the deer hunting season and are selected by deer managers	
Either Sex Gun Season Length	Similar to the regular gun season length, except hunters may harvest bucks or does without a tag. These either sex gun seasons are not continuous.	Days
Either Sex Archery Season Length	Similar to the regular archery season length, except hunters may harvest buck or doe without a tag	Days